Adult Escapement Monitoring Program Summary 2004-2005

PORE NR/WR/06-01

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Abstract

Olema Creek, Redwood Creek, and Pine Gulch Creek are the largest undammed watersheds in coastal Marin County, California and are important streams for threatened coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*) within the central California coast Evolutionarily Significant Unit (CCCESU). The National Park Service (NPS) has conducted adult escapement surveys in Marin County watersheds since 1994. NPS results show that these watersheds have supported annual runs of coho ranging from less than 10 to more than 200 individuals. This report presents annual summary information of adult escapement results for the 2004-2005 spawning season for Olema, Pine Gulch, Redwood, and Cheda Creek.

Winter 2004-2005 represented record spawner numbers for most watersheds in coastal Marin County. Adult escapement estimates and redd totals nearly doubled from last generation of this year class in Spawner Year (SY) 2001-02. The Peak Live plus cumulative Dead (PLD) estimate and redd counts in Olema Creek (182 coho and 92 redds), John West Fork (86 coho and 45 redds), and Redwood Creek (171 coho and 93 redds) represented the highest counts recorded in the past decade of monitoring. Consistent with these record results, MMWD reported an estimated 1800 coho spawners and 496 redds for the Lagunitas Creek watershed (excluding Olema Creek), up from 286 redds and 735 live coho in SY 2001-02 (MMWD 2005).

The patterns represented in our monitoring data suggest regional influences on the coho salmon escapement observed over the past decade. Overall coho escapement within Marin County watersheds has been trending upward since the 1997-98 ENSO event likely triggered the Pacific Decadal Oscillation (PDO), shifting the dominant productivity from the Alaska Current to the California Current in the late 1990s. Since 1999, all three coho year classes in Olema Creek and Redwood Creek have shown a strong response to these changed ocean productivity patterns. This upward trend is most prominent in the documented return of coho salmon to the Pine Gulch Creek watershed in winter 2000-2001.

All monitored watersheds show the pattern of two stronger year classes SY 2003-04 (Year Class 1) and SY 2004-05 (Year Class 2), and one weak year class, SY 2005-06 (Year Class 3). The strongest year class prior to the 1997-98 ENSO event, we surmise that Year Class 3, was severely impacted as fish attempted to overwinter during the El Nino winter. As a result, anticipated coho escapement for SY 2005-06 is less than that observed the past two years.

This research is conducted under the Endangered Species Act Section 10 Permit #1046 authorization managed by NOAA - Fisheries. Funding to support monitoring activities was provided through the National Park Service - San Francisco Area Network Inventory and Monitoring Program and the California Department of Fish and Game Fisheries Restoration Grant Program Contract P0330431.

Acknowledgements

Monitoring efforts on Olema Creek and Rewood Creek date back to 1994, with the institution of winter adult spawner surveys by volunteers of the Tomales Bay Association in cooperation with NPS staff. This effort evolved into a five-year National Park Service funded Coho and Steelhead Restoration Project (CSRP). The current monitoring program was initiated under the CSRP with original development by David Manning, Ron Smith, Brannon Ketcham and David Press. The program staff for the 2004-2005 monitoring efforts included our field team leader, Kirsten Leising and our Marin Conservation Corps/Americorp program intern, Bethany Craig.

Through the years, volunteers have contributed thousands of hours to these programs assisting with all aspects of our monitoring efforts. A great number of people were integral to the continued development and implementation of this program including John Eschelbach, Peter VanderNaillen, Jim White, Rusty Reniers, Rita Huppe, Stephen Samual, Julie Litwin, NoahLani Litwinsella, Courtney Johnson, James Griffiths, Jeanette Duffels, Wilson Yee, Bethany Craig, and Kirsten Leising.

We also would like to express our appreciation to Darren Fong, Aquatic Ecologist at Golden Gate National Recreation Area, who has provided continual technical review and assistance for the program since drafting the original proposal in 1996.

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1.0 BACKGROUND AND OBJECTIVES

Annually, spawner surveys are conducted in watersheds within and adjacent to SFAN Park units, including Point Reyes National Seashore (PORE), Golden Gate National Recreation Area (GOGA), and Muir Woods National Monument (MUWO). These surveys concentrate primarily on federally endangered coho salmon (*Oncorhynchus kisutch*) and federally threatened steelhead (*O. mykiss*). Occasionally, Chinook salmon (*O. tsha*) have also been observed. The watersheds within Coastal Marin County and summarized in this report, including Olema Creek, Redwood Creek, Pine Gulch Creek, and Lagunitas Creek (Figure 1.1) are considered to support the most southerly stable populations of coho salmon.

The report summarizes the 2004-05 spawning results for the monitored watersheds. Surveys are conducted weekly between December and February, but are highly dependent upon the precipitation accumulations during the season. Redds, live fish, and carcasses are counted in an attempt to better understand trends in abundance and distribution.

1.1 Introduction and History

Because adult salmon returning to the watersheds to spawn pique the interest of people, there is a long history of adult spawner observations in the area. MUWO staff began recording spawning fish observations on portions of Redwood Creek in 1944. Infrequent surveys were performed by the California Department of Fish and Game and local visitors from 1969 to 1986. In 1993, GOGA and PORE biologists initiated more detailed surveys on Redwood Creek and assisted the Tomales Bay Association (TBA) with surveys on Olema Creek. The first complete surveys of Olema Creek were undertaken in the winter of 1995-96 by the TBA and PORE. Systematic monitoring within the SFAN watersheds was not initiated until the mid-1990s.

The Coho and Steelhead Restoration Project (CSRP) was initiated in 1997 and continued the work began by the TBA and previous NPS biologists with comprehensive surveys of Olema Creek, Redwood Creek, Cheda Creek (a Lagunitas Creek tributary) and Devil's Gulch (a Lagunitas Creek tributary) in the winter of 1997. To increase the value of the information collected during spawning surveys, and enable comparison of data from year to year, the CSRP began efforts to standardize methods and test different survey methodologies. Marin Municipal Water District (MMWD) took over Surveys on Devil's Gulch starting in the winter of 2000. With the discovery of coho salmon on Pine Gulch Creek during the winter of 2000-2001, spawner surveys were expanded to include Pine Gulch Creek in yearly monitoring efforts. In 2003, the fisheries monitoring efforts were incorporated into the San Francisco Bay Area Network (SFAN) Stream Aquatic Monitoring Program. Protocols to document field and analytical methods have been developed for the adult escapement monitoring efforts (Ketcham et. al 2005a).

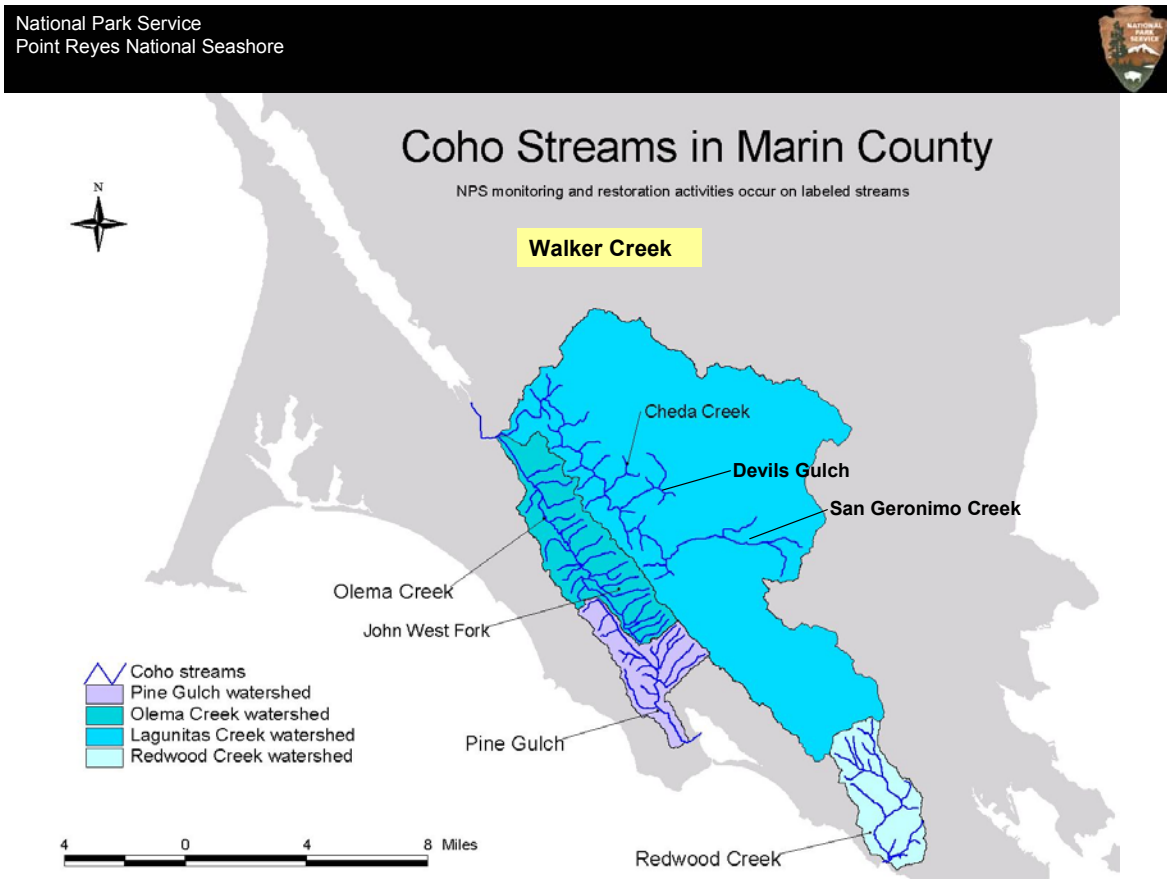

Figure 1.1 Map of coho streams in Marin County.

1.1.1 Coho Salmon

Biology

The general biology of coho salmon is described in detail in Hassler (1987) and Sandercock (1991). The coho salmon is an anadromous, semelparous fish species, migrating from marine water back to freshwater for a single chance at reproduction. Coho generally return to natal streams after spending two years in the ocean. The spawning migrations begin after heavy late-fall or winter rains breach the sandbars at the mouth of coastal streams allowing the fish to move upstream. Spawning occurs in small to medium sized gravel at aerated sites, typically near the head of a riffle (Moyle 1976). These streams have summer temperatures seldom exceeding 21 degrees Centigrade (70 degrees Fahrenheit). Emergent fry use shallow near-shore areas, whereas optimal habitat conditions for juveniles and sub-adults are deep pools associated with rootwads, woody debris, and boulders in shaded stream sections (Laufle et al 1986).

Because of dramatic declines in population numbers, the National Marine Fisheries Service (NMFS) was petitioned to list this species coastwide (NMFS 1996). Causes of coho salmon declines in California include incompatible landuse practices such as logging and urbanization, loss of wild stocks, introduced diseases, over harvesting, and climactic changes.

Coho salmon are known to exist in watersheds including Lagunitas, Olema, Pine Gulch (Brown and Ketcham 2002), and Redwood Creeks. Walker Creek, which flows into Tomales Bay, likely supported coho salmon and is part of a larger coho recovery program conducted by the California Department of Fish and Game and NOAA-Fisheries.

Regulatory Protection

NOAA-Fisheries
Coho salmon were listed as a threatened species within the central California coast coho salmon ESU (CCCESU) on October 31, 1996 by the National Marine Fisheries Service (NOAA-Fisheries) (Federal Register 1996). The CCCESU (Figure 1.2) includes all naturally spawned populations of coho salmon from Punta Gorda in northern California south to and including the San Lorenzo River in central California, as well as populations in tributaries to San Francisco Bay, excluding the Sacramento-San Joaquin River system. The original listing criteria stated that the Lagunitas/Olema Creek population accounted for more than 10% of the wild coho population (Brown et al 1994) in the CCCESU. Recent research through the NPS, Marin Municipal Water District (MMWD), and Salmon Protection and Watershed Network (SPAWN) have shown that the Lagunitas population likely represents more than 20% of the CCCESU population.

In association with the coho threatened listing NOAA-Fisheries designated critical habitat for coho salmon on May 5, 1999 (Federal Register 1999). The critical habitat is designated to include all river reaches accessible to listed coho salmon from Punta Gorda in northern California south to the San Lorenzo River in central California, including Mill Valley (Arroyo Corte Madera Del Presidio) and Corte Madera Creeks, tributaries to San Francisco Bay. Excluded are areas above specific dams or above longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years). Major river basins containing spawning and rearing habitat for this ESU comprise approximately 4,152 square miles in California. The following counties lie partially or wholly within these basins: Lake, Marin, Mendocino, San Mateo, Santa Clara, Santa Cruz, and Sonoma.

In their 2001 Status Review, NOAA-Fisheries acknowledged that within the CCCESU, the decision to list coho salmon as threatened may have been overly optimistic, concluding that the ESU population was presently endanger of extinction (NMFS 2001). As a result of these and further findings, NOAA-Fisheries completed a rulemaking process in June 28, 2005, which downgraded the coho status (upgraded listing protection) in the ESU to Endangered (Federal Register 2005a).

California Department of Fish and Game
On April 5, 2001, the Fish and Game Commission accepted the petition to list coho salmon north of the Golden Gate as endangered under the State Endangered Species Act. As a response to this petition, the DFG prepared a status review of California which concluded that the coho salmon within the central California coast ESU (as designated by NOAA Fisheries – Figure 1.2) are in serious danger of becoming extinct throughout all or a significant portion of its range, and that the endangered listing is warranted (CDFG 2002). As a response, the CDFG released a draft Recovery Strategy for coho salmon in November 2003, which was adopted as revised by the Fish and Game Commission on February 6, 2004. On August 5, 2004, the Fish and Game Commission added coho salmon populations between San Francisco and Punta Gorda to the list of species protected under the Endangered Species Act (areas south of San Francisco were already listed as endangered). This listing became effective March 30, 2005.

1.1.2 Steelhead

Biology
Steelhead are the anadromous form of rainbow trout; adult steelhead typically spawn in gravel riffles in the spring, from February to June. Steelhead are multiparous, meaning they can spawn more than once. Research conducted in the 1950s documented female steelhead returning to spawn in multiple years (Shapavolov and Taft 1954). Optimum temperatures for growth range from 13 to 21 degrees Centigrade (55 to 70 degrees Fahrenheit) (Moyle 1976). It is also noted that steelhead may persist in a broad range of pH (from 5.8 to 9.6) but prefer a pH between 7 and 8 (Moyle 1976). Steelhead fry reside in near-shore

areas. Steelhead juveniles tend to use riffles and pool margins. Because of dramatic declines in population numbers, the National Marine Fisheries Service (NMFS) was petitioned to list this species throughout much of the California coast.

Steelhead trout are known to exist in most perennial watersheds within Marin County.

Regulatory Protection

Steelhead were listed as a threatened species on August 17, 1997 (Federal Register 1997). The central California coast steelhead ESU (Figure 1.2) includes all naturally spawned populations of steelhead (and their progeny) in California streams from the Russian River to Aptos Creek, and the drainages of San Francisco and San Pablo Bays eastward to the Napa River (inclusive), excluding the Sacramento-San Joaquin River Basin. Critical habitat for steelhead is under development. On April 30, 2002, the U.S. District Court for the District of Columbia approved a NMFS consent decree withdrawing a February 2000 critical habitat designation for this and 18 other ESUs. In 2005, the final rule for critical habitat was published in the Federal Register (Federal Register 2005b).

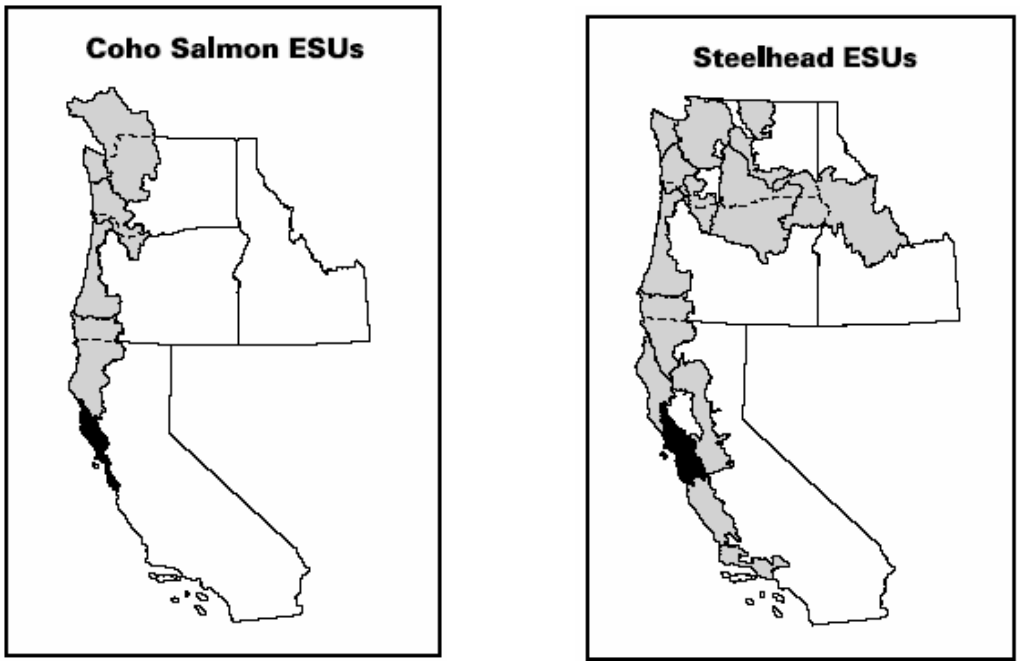

Figure 1.2 Coho salmon and Steelhead Evolutionarily Significant Units as identified by NOAA Fisheries. Marin County is included within the Central California Coast ESU for coho salmon (left) and steelhead (right).

1.1.3. Chinook Salmon

California Coastal Chinook salmon were listed as threatened on September 16, 1999; threatened status reaffirmed on June 28, 2005. The ESU includes all naturally spawned populations of Chinook salmon from rivers and streams south of the Klamath River to the Russian River, California. Though not included in the listed area, adult Chinook salmon have been observed within Lagunitas Creek in increasing numbers since 2000 (MMWD 2003). The increasing frequency of Chinook salmon within Lagunitas Creek may indicate the development of a self-sustaining population, but whether this will persist is unclear (NOAA Fisheries 2004). Because of the proximity of these fish to the southern boundary of the ESU, NOAA Fisheries has treated this watershed population as part of the California Coastal listed population for the purposes of other consultations on the lands of Point Reyes National Seashore and Golden Gate National Recreation Area (NOAA Fisheries 2004).

1.1.4. Essential Fish Habitat

The Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267) requires all Federal agencies to consult with NMFS on all actions, or proposed actions, permitted, funded, or undertaken by the agency, that may adversely affect Essential Fish Habitat (EFH). EFH is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." "Waters" include aquatic areas and their associated physical, chemical and biological properties. "Substrate" includes sediment underlying the waters. "Necessary" means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem. Spawning, breeding, feeding, or growth to maturity covers all habitat types utilized by a species throughout its life cycle. NMFS would provide recommendations to conserve EFH to Federal or state agencies for activities that would adversely affect EFH.

1.1.5 Salmonid Genetics

The NOAA-Fisheries Genetics Laboratory reports that the coho salmon in the CCCESU are represented by five general subpopulations. While most show some influence from former hatchery production, the coho populations from Redwood Creek (GOGA, MUWO) represent a genetically distinct subgroup in the CCCESU that has not been influenced by historic salmon stocking (Garza and Gilbert-Horvath, 2003). Genetic tests also indicate that coho which have returned to Pine Gulch Creek after a thirty year absence were likely strays from Redwood Creek, representing a natural expansion of this genetically distinct and significant stock to a new watershed within PORE (Garza and Gilbert-Horvath, 2003). Populations of coho within Olema Creek and Lagunitas Creek are generally considered to occur within a Tomales Bay sub-population, with no significant genetic distinction between Olema and Lagunitas Creek.

In 2005, Garza and Spence (NOAA) reported results of a statewide steelhead genetic analysis. One of the most pertinent findings to this study area were that the steelhead samples from coastal Marin watersheds, Lagunitas, Olema, and Redwood Creek watersheds showed the greatest number of allele, used as an indicator for population robustness through the NOAA-Genetics Lab (Garza and Spence 2005)

1.2 Watershed Background

Olema Creek is the largest undammed watershed in coastal Marin County, California and an important stream for coho salmon and steelhead within the CCCESU. The 15.9 km stream flows northwest through the Olema Valley, the landward expression of the San Andreas Fault Zone. It's confluence with Lagunitas Creek lies at the head of the ecologically significant Tomales Bay. Protected from development, the 14.5 square mile watershed is primarily contained within the boundaries of Point Reyes National Seashore and the Golden Gate National Recreation Area North District. The watershed provides habitat to four federally protected aquatic species (California freshwater shrimp – endangered; coho salmon – endangered; steelhead – threatened; California red-legged frog – threatened). Olema Creek is the focal point of hydrologic, water quality, and fisheries monitoring within Point Reyes National Seashore.

Redwood Creek is a 7.5 square mile coastal watershed in southern Marin County, California. Redwood Creek flows southwest from the flanks of Mt Tamalpais, through Muir Woods National Monument, discharging to the Pacific Ocean through Big Lagoon at Muir Beach, CA. Protected from development, the watershed is primarily contained within the boundaries of Mt Tamalpais State Park, Golden Gate National Recreation Area and Muir Woods. The watershed provides habitat to coho salmon – endangered; steelhead – threatened; and the California red-legged frog – threatened. Redwood Creek supports a genetically distinct sub-group of coho salmon (Garza and Gilbert-Horvath 2003) within the Central California Coast Evolutionarily Significant Unit (CCCESU).

Pine Gulch Creek drains a 7.5 square miles watershed in coastal Marin County, California, and is the primary freshwater input to Bolinas Lagoon. Pine Gulch Creek is located within the CCCESU where coho salmon and steelhead occur. The watershed supports a population of steelhead and it is generally accepted that it supported a native self-sustaining population of coho salmon into the 1970's. It is likely that the drought of the late 1970's coupled with in-stream damming during the same period severely depleted multiple year classes and led to unsuitable conditions for continued survival of the species within the Pine Gulch watershed. In 2001, NPS documented return of coho salmon to the watershed beginning with recovery of a coho carcass, and subsequent documentation of coho juveniles in the watershed the following

summer (Brown and Ketcham 2002). Monitoring indicates that all three coho cohort year classes are represented within Pine Gulch Creek (Ketcham and Brown 2003).

Cheda Creek is a small but important tributary of the Lagunitas Creek watershed and provides critical habitat for steelhead trout and coho salmon. Past land-use within the Cheda Creek drainage has resulted in serious alterations to the natural hydrologic and riparian condition of the creek. These factors have negatively impacted salmonid populations, water quality, and the ability of the aquatic ecosystem to function properly. The construction of a fish passage structure in the fall of 2000 was part of an overall watershed restoration project designed by the National Park Service (NPS) to restore the system to a more natural and sustainable condition.

This report summarizes the 2004-2005 spawner season on Redwood Creek, Olema Creek, Pine Gulch Creek, and Cheda Creek watersheds. Detailed results have previous years have been reported in previous documents.

1.3 Rationale for Adult Escapement Monitoring Program

1.3.1 Monitoring Objectives

The objectives of the adult escapement monitoring program are:

1. Determine long-term changes in timing and distribution of salmonid spawning, adult sex ratios, and escapement estimates in select streams at PORE and GOGA.
2. Develop a population genetic structure and age-size relationship for salmonids through genetic sample collection and processing.

1.3.2 Monitoring Questions

- What are the overall salmonid condition and trends within PORE, GOGA, and MUWO watersheds?
- Are parks meeting resource protection mandates relative to salmonid habitat protection?
- What habitat constraints exist in the parks that currently impede or limit salmon recovery efforts?
- What are park salmonid population distribution and trends by watershed and year class?
- Are the salmonid populations stable within the PORE, MUWO, and GOGA watersheds?
- Is the data collected in SFAN streams for salmonids comparable with data collected for salmonids in other watersheds in the region?
- What is the aquatic habitat and biotic response to restoration actions including fish passage, streambank stabilization, woody debris placement, riparian protection, etc.?

2.0 SAMPLING DESIGN AND METHODS

NPS staff and trained volunteers conduct surveys each winter during the coho spawning season to quantify escapement and determine spawning density and distribution. Although surveys focus on coho, steelhead spawners and redds are observed and counted during the surveys. Surveys are spaced approximately every week, although storms and high stream flows often dictate less frequent surveys. Teams of two to four observers walk upstream through 2-4 km reaches, along creek margins and banks where possible, and look for live fish, carcasses, and redds. Live fish are identified to species and sex, and lengths are visually estimated. Carcasses are measured (fork length), identified to species and sex, and marked to prevent double counting. Carcass scales and tissue samples are collected for age and genetic analysis. Scales samples are only collected from fresh (both eyes are still clear) carcasses that have not been mauled by scavengers. Redds are measured and marked with flagging. Redd monitoring is targeted as they are stationary and can be monitored over time to determine spawning success. In northern California, a model has been developed to estimate spawning population based upon redd count and redd effort (Gallagher and Gallagher 2004). These estimates are derived from redd measurements currently collected through the monitoring protocol. The NPS plans to work with CDFG researchers to calibrate the model to monitoring in this area.

Particular care is taken not to disturb redds or actively spawning adults. Locations of all live fish, carcasses and redds are recorded in reference to permanent tags placed every 100 meters along each stream. Through experience, we have found volunteers effective at documenting live fish and carcasses, but not as effective at documenting redd presence or sex of the individual fish. SFAN staff conduct follow-up redd surveys to confirm those marked, and identify those missed in earlier surveys. The survey data is used to generate index values and minimum population estimates for the assessment of long term trends.

Because coho return to spawn over a one to three-month period November through January (weather dependent) and residence time on the spawning grounds is variable, live fish may be double counted during repeated surveys. Reported spawning escapement estimates are made using the Peak Live + Cumulative Dead (PLD) index. This index is derived by adding the peak number of live fish observed during a single survey to the number of carcasses recovered on or prior to that date. Carcass information is also used to calibrate observer length and sex estimates. Redd counts are used to describe spawning density and spatial distribution. Where survey frequency is adequate, reporting will include escapement estimates using the Area Under the Curve (AUC) method (Irvine et al. 1992).

Spawner surveys for a watershed the size of Olema require the mobilization of 10-15 volunteers from the local community. Many of these observers are experienced and are able to lead teams for the survey. SFAN program staff lead as many teams as feasible. An SOP for implementation of the adult escapement monitoring program, including field procedures and methods for analysis are documented in the Stream Aquatic Resource Monitoring Protocol SOP 3 - Adult Escapement Monitoring Program Protocol (Ketcham et. al 2005a).

2.1 Rationale for selecting this sampling design

The methodologies currently used for spawner surveys have been used to estimate escapement for a variety of salmonids throughout the Pacific Northwest (Johnston et al. 1987; Irvine et al. 1992; Anderson and McGuire 1994; Downie and Peterson (undated)). Although both steelhead and coho are present in PORE and GOGA watersheds, the surveys focus on coho because their life history pattern and behavior is more amenable to accurate data collection. Coho spawner survey data tends to be more accurate than steelhead information because:

1. coho spawn earlier than steelhead (typically in December or January);
2. unlike steelhead, coho remain in the watershed until they die after spawning, which makes carcasses readily collectible;
3. steelhead spawn over a longer period than coho, from January to May, which makes the frequent collection of data more difficult.

2.2 Site selection

Watersheds that are part of the adult escapement monitoring program include Olema, Pine Gulch, Redwood and Cheda Creek. These watersheds are primarily or wholly within the NPS legislative boundaries. Salmonids in these watersheds are not monitored by other entities, therefore collection of these watershed data are important for park managers. Spawner surveys have been conducted on many of these watersheds since the early to mid-1990s. Monitoring effort and protocols were standardized with the implementation of the CSRP in 1997.

2.3 Number and location of sampling sites

2.3.1 Olema Creek

A large section of the mainstem of Olema Creek, 17.6 km, has been surveyed by the TBA and PORE staff and volunteers since 1993. The section is currently divided into 7 survey reaches starting one kilometer above the confluence with Lagunitas Creek and ending at the Highway 1 culvert at milepost 19.94. Reaches are delineated to facilitate sampling based on access, length, and the existence of permanent landmarks for reach boundaries (Figure 2.1). The existing seven reaches extend from:

1. one kilometer above the confluence with Lagunitas Creek to the Bear Valley Road Bridge in the town of Olema (1.6 km);
2. The Bear Valley Bridge to the confluence with Truttman Creek (3.2 km);
3. Truttman Creek to the horse trail crossing at the Stewart Ranch (2.6 km).
4. Stewart Ranch to the first Hwy. 1 bridge at Five Brooks (1.3 km);
5. Five Brooks to the abandoned Lime Kilns (2.8 km);
6. The Lime Kilns to the abandoned Randall ranch house (1.7 km);
7. The Randall House to the Hwy. 1 culvert at milepost 19.94 (4.1 km);

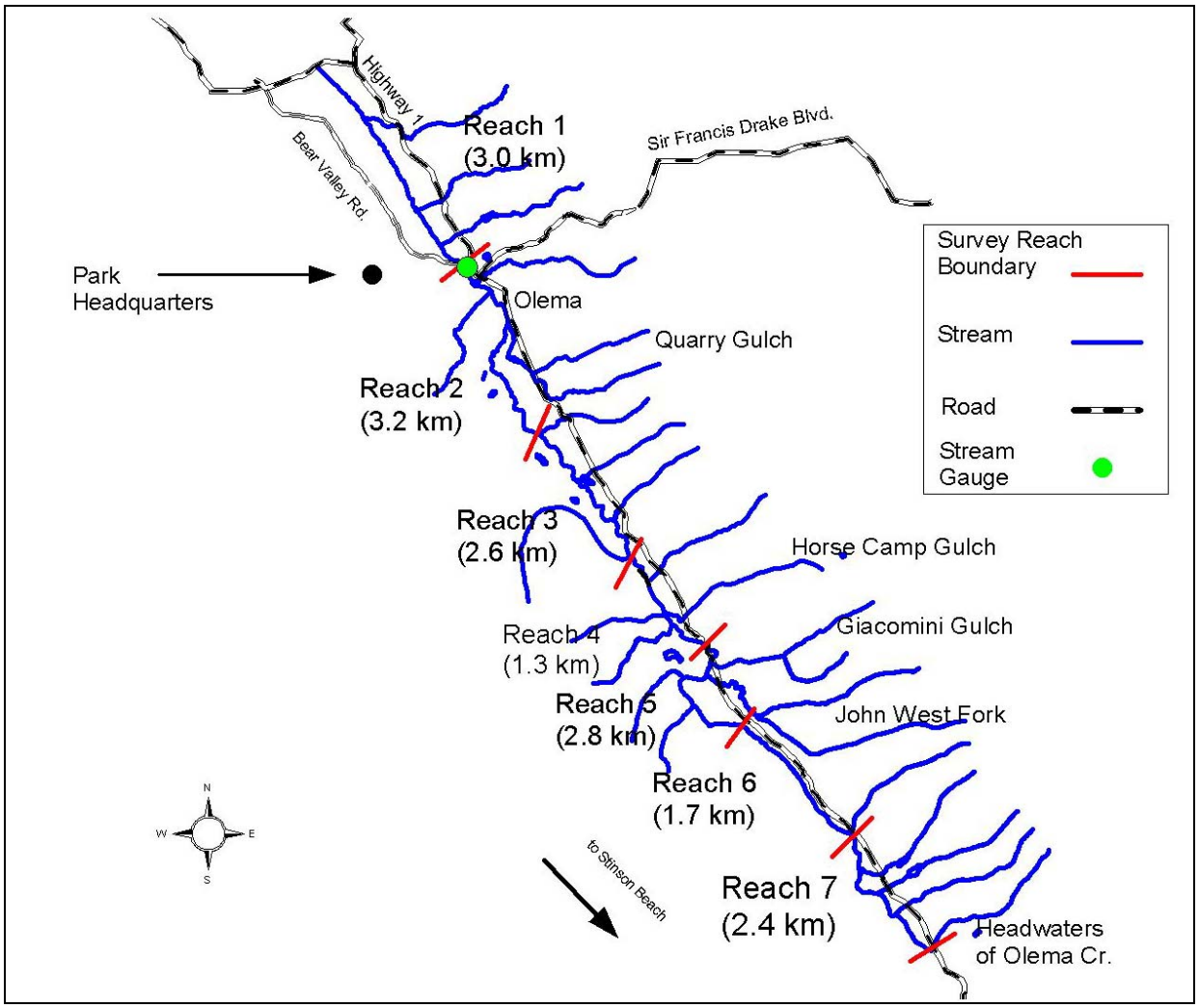

Figure 2.1 Olema Creek Spawn Survey Reach Map

In addition to the mainstem of Olema Creek, surveys are often conducted on some of the larger tributaries. Most tributary surveys conducted in the past were intended only to establish presence or absence of spawning coho and reach lengths varied widely. At present, complete surveys are conducted for the tributaries as personnel and flow conditions allow, based on order of priority. For each tributary, survey reaches start at the mouth and generally continue upstream as long as no passage barriers exist. The tributaries, many of them unnamed on U.S. Geological Survey (USGS) 7.5 minute maps, are named in Figure 2.1 and listed in order of survey priority:

1. John West Fork located 10.9 km above the mouth of Olema Creek at Hwy. 1 milepost 22.67. (survey reach from trib mouth to 2 km upstream)
2. Quarry Gulch located close to the Olema Cemetery 4.1 km above the mouth of Olema Creek at Hwy. 1 milepost 25.35.
3. Giacomini Gulch located 10.8 km above the mouth of Olema Creek at Hwy. 1 milepost 22.78.
4. Horse Camp Gulch located 9.6 km above the mouth of Olema Creek at Hwy. 1 milepost 23.26.
5. The Headwaters of Olema Creek (considered a tributary for the purposes of the survey due to its physical characteristics) beginning at Hwy.1 milepost 19.94.

2.3.2 Redwood Creek

Since 1994, the NPS has conducted annual surveys along a 6.7 km section of the mainstem of Redwood Creek (Figure 2.2) between a point 140 m below the Pacific Way Bridge and a large debris jam 500 m above Bridge 4 in Muir Woods. The section encompasses most of the stream length used by coho salmon. To facilitate sampling, the section is divided into three reaches;

1. Pacific Way Bridge to the Kent Creek confluence in Mt. Tamalpais State Park (2.7 km),
2. Kent Creek confluence to Bridge 1 in Muir Woods (2.4 km) and,
3. Bridge 1 to 500 m above Bridge 4 (1.6 km).

Portions of Fern and Kent Creeks, the two largest Redwood Creek tributaries, will also be sampled. The reach on Kent Creek extends from the confluence with Redwood Creek to a water fall, approximately 1 km upstream, that is impassable to migrating adults. The Fern Creek section has been surveyed since 1994 and extends between the Redwood Creek confluence and a series of steep cascades 1 km upstream. The debris jam that serves as the upstream limit of surveys on Redwood Creek and the high gradient cascade on Fern Creek are not impassable barriers for steelhead. However, neither coho salmon adults nor juveniles have been observed above these points and they are assumed to be coho barriers.

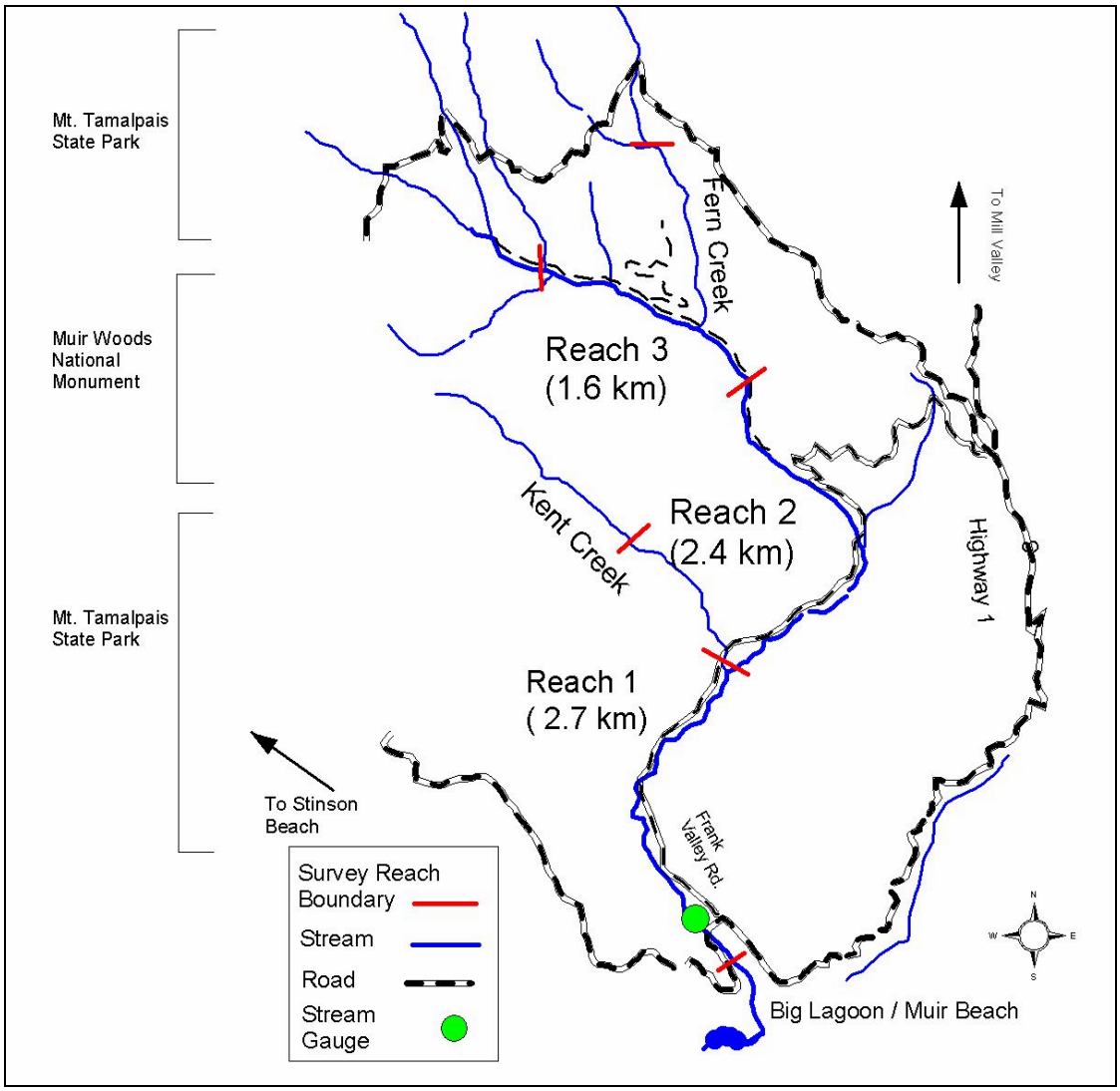

Figure 2.2 Redwood Creek adult escapement monitoring program survey reaches.

2.3.3 Pine Gulch Creek

Since 1997, the NPS has conducted surveys along a 9 km section of the mainstem of Pine Gulch Creek. Coho salmon were first spotted during surveys in the winter of 2000-2001. Due to private property access issues and the nature of the watershed, the survey reaches are longer than normal (Figure 2.3). This requires a solid day to conduct the survey with two teams. Additional surveyors are required to complete the McCurdy Tributary.

The spawner surveys start at the Olema-Bolinas Road Bridge and extend upstream to at-least the Teixeira Ranch. Complete surveys should extend up the mainstem to the Pacific Coast Learning Center/Hagmaier complex. The section encompasses most of the stream length that would be potentially used by coho salmon.

Currently sampled reaches include:

1. Olema-Bolinas Road Bridge to the Copper Mine Gulch confluence (6.0 km).
2. Copper Mine Gulch– Upstream beyond Teixeira to approximately monument marker 100 (3.5 km).

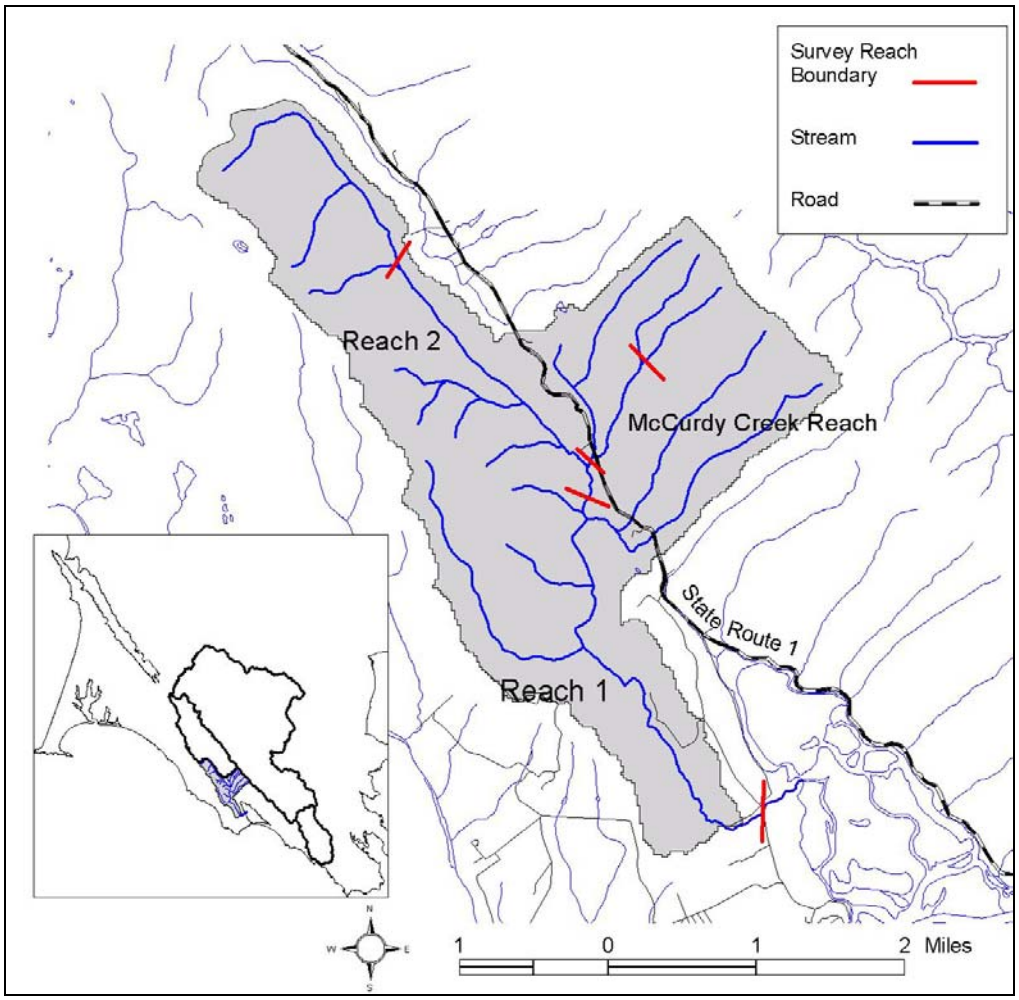

Figure 2.3 Pine Gulch Creek adult escapement monitoring program survey map.

2.3.4 Lagunitas Creek Watershed - Cheda Creek

Lagunitas Creek and its tributaries (Nicasio Creek, San Geronimo Creek, Devil's Gulch, Cheda Creek, Bear Valley Creek, and Olema Creek) drain more than 230 square kilometers of western Marin County.

The headwaters of the Lagunitas Creek mainstem lie within the 53,000 ha watershed lands administered by MMWD. The mainstem originally totaled about 40 km of perennial stream draining the northern slope of Mt. Tamalpais, but was reduced by more than 50% by construction of Alpine Dam in 1918 and Peters Dam in 1953. Because neither dam has provision for fish passage, their construction resulted in permanent loss of the upper portion of the drainage to anadromous fish.

The portions of the Lagunitas drainage most significant for salmonids are under a number of ownerships. Approximately 12 km of the mainstem is bordered by NPS lands (north district Golden Gate National Recreation Area). A major tributary, San Geronimo Creek, flows through privately held land in San Geronimo Valley. Devil's Gulch lies almost entirely within Samuel P. Taylor State Park with its headwaters in NPS lands. Only one smaller tributary of Lagunitas Creek, Cheda Creek, lies entirely within GGNRA lands.

Cheda Creek (Figure 2.4), a Lagunitas Creek tributary, has been surveyed since 1996-97 to detect the presence or absence of coho. The NPS completed a fish passage project in the fall of 2000, coho salmon spawning in the upper part of the creek above the fish passage project site was detected in the 2004-05 spawning season. Approximately 1.3 km of stream is typically surveyed, including a 0.8 km reach below the fish passage improvement and 0.5 km reach above.

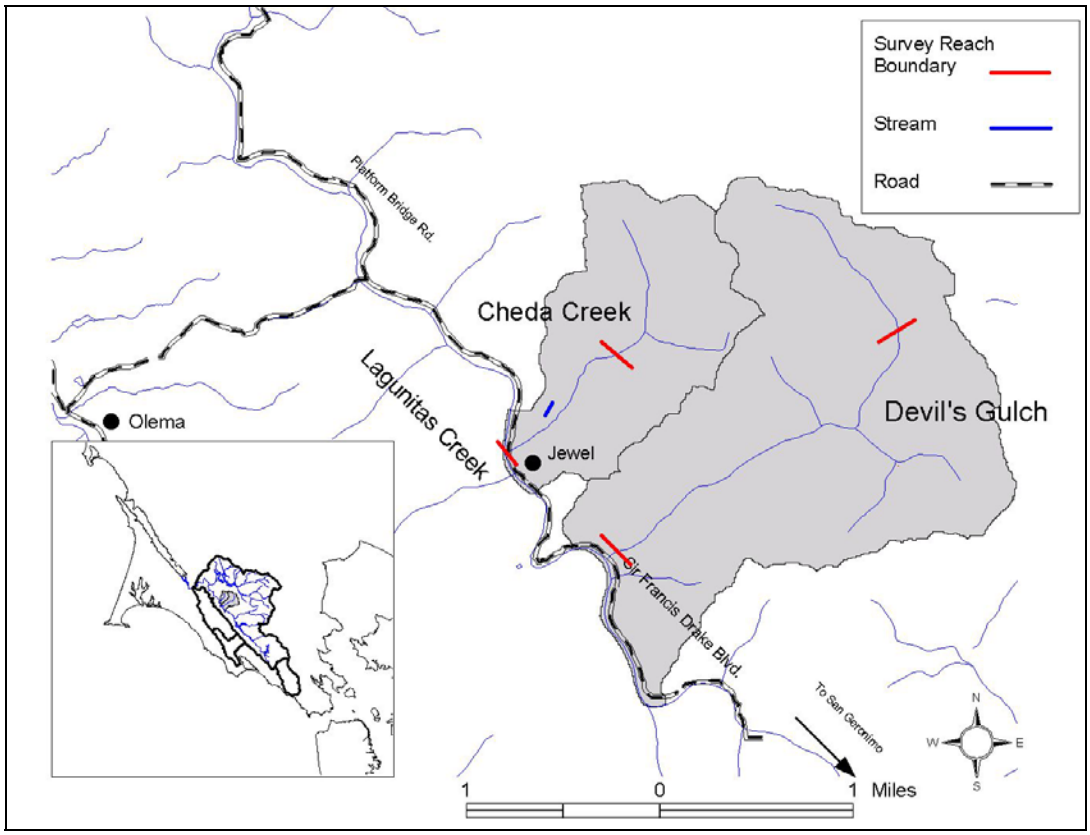

Figure 2.4 Adult escapement monitoring program survey reach map for Cheda and Devil's Gulch

2.4 Recommended frequency and timing of sampling

Sampling duration is driven by both streamflow and visibility conditions. In these unregulated watersheds, streamflows required to facilitate salmon access to the watersheds occur between November and January

based on rainfall (see Table 7.2 and 7.9 for coho run timing in Olema and Redwood Creeks). The typical spawning season for coho is late November into early February, while steelhead typically show up to spawn between January and March. In Lagunitas Creek, where required releases occur from the reservoir system, Chinook salmon have been observed for the past 5 years, commonly entering the watershed between November and December. Within our unregulated watersheds, spawner response is concentrated in one or two storm related flow or freshet events.

Based on female redd residency times watersheds should be surveyed weekly to accurately capture redd timing (Burton et al. 2002; van den Berghe and Gross 1986). Because the surveys are confounded by environmental factors (stream discharge and turbidity), as well as scheduling around the holidays, the surveys are often less frequent.

2.5 Level of change that can be detected for the amount/type of sampling being instituted

The adult escapement surveys are most affected by weather and flow response in the creek. Because of the variability and uncertainty with these parameters each year, the spawning run is typically summarized by the PLD (peak live + cumulative dead) index, which gives an estimate of minimum escapement. Using this index, the NPS has been able to characterize changes in each year class, as well as predict strength of run between years. Spawner survey results are especially valuable in conjunction with the other seasonal monitoring programs for predicting trends within and between salmonid year classes.

Since 1999, within monitored watersheds, the results of salmonid monitoring have shown a dramatic response in all year classes to the El Nino-Pacific Decadal Oscillation adjustments that occurred in 1998. We have documented a 100% increase in adult escapement to Olema and Redwood Creek, as well as the return of coho salmon to Pine Gulch Creek. The redd survey information is something that has been identified locally as a very effective means of tracking adult escapement annually as well as by year class. Locally, redd data information is used to compare results between watersheds. Continued collection of redd density and distribution information may become a better indicator of change than the adult counts.

2.6 Routine data summaries and statistical analyses to detect change

The analysis of spawner survey data is complicated by annual variability in environmental conditions and run characteristics. Accurate abundance estimates are difficult to generate without counting weirs or other intensive sampling techniques (Irvine et al. 1992). The NPS monitoring program is, nonetheless, interested in developing precise indices of abundance. In addition to cumulative redd count, two techniques, Peak Live Plus cumulative Dead (PLD) and Area Under the Curve (AUC) are used to compute coho salmon escapement index values (Beidler and Nickelson 1980; Johnston et al. 1987). In addition to calculating the indices, we summarized the live fish, redd, carcass, and environmental data for each stream.

The PLD and AUC estimates provide different types of information. While the PLD index produces a minimum instantaneous estimate, the AUC method is used to calculate a total population estimate. The PLD index is computed as the name suggests. The peak number of live fish observed during a single day of the spawning season is added to the cumulative number of unmarked carcasses observed prior to that date. The AUC estimate is calculated using the total number of live fish observed during each survey and the average life of fish on the spawning grounds (residence time). Calculating the area under the curve created by plotting the live fish observations for each survey, produces a quantity termed total fish-days. The area under the escapement curve was given by:

$$\mathbf{AUC = 0.5 \{ \sum (t_i - t_{i-1}) (p_i + p_{i-1})\}}$$

where t_i is the number of days since the first fish entered the survey area and p_i is the total number of fish observed on the i^{th} day (Irvine et al. 1992). Dividing the total number of fish days by the residence time gives the population estimate. Because we did not estimate residence time, separate AUC estimates were computed using the range of values, 8 to 17 days, presented in the literature (Moring and Lantz 1975; Johnston et al. 1987; Irvine et al. 1992). Data collection typically stops after repeated surveys no longer indicate the presence of live coho. High flows often prevent staff from conducting surveys during

significant portions of some spawner seasons. If fish were observed during the last survey of the season, the last date used for calculating the AUC estimate was arbitrarily set at 10 days after the final survey date.

Because the necessary conditions for accurate AUC estimates are not always met, we also quantify spawning runs using the Peak Live + Cumulative Dead (PLD) index. This index is derived by adding the peak number of live fish observed during a single survey to the number of carcasses recovered on or prior to that date, and is considered a minimum count. Redd count and location is used to describe spawning density and spatial distribution.

3.0 2004-2005 OLEMA CREEK ADULT COHO ESCAPEMENT RESULTS

Olema Creek survey information includes data collected on the mainstem, primarily reaches 2-7, and John West Fork (see Figure 2.1). Calculation of these surveys treats these as separate watersheds.

Rainfall and moderate flows in early December were conducive to coho spawning while still allowing adequate visibility for good surveys. Peak spawning was observed in both mid December and early January, with 134 live coho observed on 15 December 2004 and 45 live coho were observed 21 days later, on 6 January 2005. A total of 92 redds were distributed along the mainstem of Olema Creek starting at the Bear Valley Road bridge.

Two peaks were observed on the John West Fork (JWF) with the first peak of 48 fish occurring on 10 December 2005 and the second peak of 38 fish occurring on 29 December 2005. In the John West Fork 45 redds were observed. Peak spawning on JWF coincided with those observed on the mainstem of Olema Creek.

3.1 Survey Timing and Environmental Conditions

Six surveys were conducted in Olema Creek between 2 December 2004 and 9 February 2005 (Table 3.1). The mean interval between surveys was eleven days. Mean daily flow during the surveys ranged from 8.15 cfs on December 15 to 48.42 cfs on January 6. Average water clarity at the time of surveys ranged from 35 to 150 cm. Water clarity was greater than 50 cm in over 90% of the surveys. The onset of higher flows appeared to be related to live fish observations.

Table 3.1 Daily average flow, 7 day total rainfall per Julian week, 7 day average flow per Julian week, average water clarity, and the number of live coho observed in 2004-05 on the mainstem of Olema Creek.

Julian Week	Survey Date	Survey Reaches	Calendar Day	Daily Average Flow on Survey Date (cfs)	7 Day Rainfall during Julian Week (in)	7 Day Average Flow During Julian Week (cfs)	Average Survey Water Clarity (cm)	Coho Redds	Coho Carcass	Live Coho
47					0.03	1.10				
48					0.61	1.05				
49	2 Dec 04	2-3	337	0.89	0.03	0.96	102	0	0	0
50					4.66	117.15				
51	15 Dec 04	2-6	350	8.15	0.09	8.54	107	55	6	134
52	21 Dec 04	2-6	356	6.97	0.03	8.37	100	16	21	89
1					5.53	137.96				
2	6 Jan 05	2-7	6	48.42	2.07	71.27	70	19	17	46
3					0.90	20.35				
4	18 Jan 05	2-6	18	31.51	0.00	6.78	120	2	18	0
5	9 Feb 05	2-6	40	19.38	1.67	31.98	107	0	1	0
6					0.02	84.75				
7					0.22	20.12				

Reach 2: Bear Valley Bridge to the confluence with Truttman Creek (3.2 km)
Reach 3: Truttman Creek to the Davis-Boucher Creek confluence at the Stewart Ranch (2.6 km)
Reach 4: Stewart Ranch to the State Route 1 bridge at Five Brooks (1.3 km)
Reach 5: Five Brooks to the abandoned Lime Kilns (2.8 km)
Reach 6: The Lime Kilns to the abandoned Randell ranch house (1.7 km)
Reach 7: The abandoned Randall ranch house to the Hwy.1 culvert at milepost 19.94 (4.1 km)

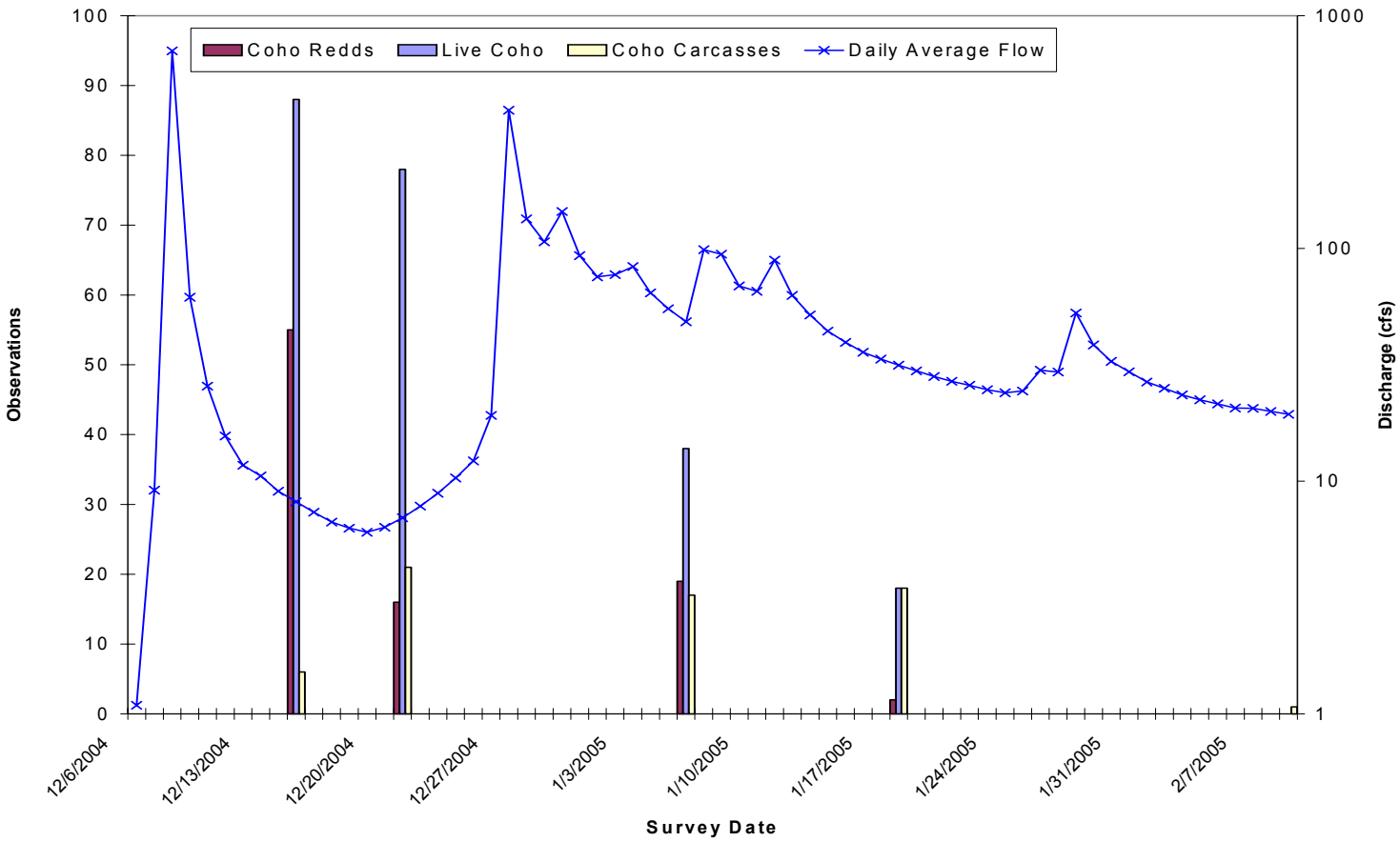

Figure 3.1 Representation of adult escapement survey results, including live fish, carcasses, and redds, observed during surveys in Water Year 2005. Discharge represents the average daily flow measured on the mainstem of Olema Creek, at the Bear Valley Road bridge.

A total of 11.6 kilometers (reaches 2-6) of the Olema Creek mainstem were consistently sampled during each survey. Reach one was not sampled due to poor spawning habitat and only brief sections of reach seven were surveyed due to access issues. Reach seven is narrow, incised, and the banks are lined with dense riparian shrubs and woody debris. Wading upstream is hazardous during even low winter flows and observation from the bank is difficult.

Five tributaries were surveyed between December and February. The timing of tributary surveys generally followed the mainstem surveys. John West Fork Creek was sampled seven times. Sections of Quarry Gulch, Giacomini Gulch, Horse Camp Gulch, and Boundary Gulch and the Olema Creek headwaters were surveyed one time.

Water clarity in John West Fork Creek ranged from 50 cm to 100 cm during the seven surveys. Clarity was usually less than 50 cm in the other five streams. The length of survey sections in each tributary varied widely depending on access and spawning habitat on each tributary (Table 3.3). The North Fork of John West Fork was surveyed two out of the seven surveys with no adult coho or redds observed. On all seven surveys on John West Fork a 2.0 km section was consistently surveyed, from the confluence of Olema creek to monument tag OL-1220.

Bankfull flow in Olema Creek, (approximately 500 cfs) (Dunne and Leopold 1978) at the Bear Valley Bridge, was equaled or exceeded for three days during December. Total precipitation recorded at the Bear Valley weather station decreased from 10.13 inches in December to 4.85 inches in January. Mean daily flows decreased from 59.1 cfs in December to 48.9 cfs in January and 44.7 cfs in February. The peak discharge observed during the survey period was 934.6 cfs observed on December 27.

3.2 Live Fish, Carcass, and Redd Observations

3.2.1 Live Fish

Coho

Between 15 December 2004 and 9 February 2005, 269 live adult coho were observed in the mainstem of Olema Creek. Because the surveys were conducted frequently, many individual fish were counted more than once. Therefore, the total number of live fish observations is not an accurate estimator of the total spawning escapement. The first 134 fish observed on December 15 was also the peak of the run (Figure 3.1). A second peak was observed on January 6 with 46 fish observed. Assuming the longest coho residence time after stream entry is 21 days (longest observed in Olema Creek under low stress conditions was 20 days) and the condition of fish observed in the January survey, it was determined that the live adult coho observed on December 15 were not recounted on the survey conducted on January 6.

Table 3.2. The number of live adult coho salmon, carcasses, and redds observed in the mainstem of Olema Creek during 2004-2005. Live fish observations do not represent the total number of spawning adults.

Survey Date	Reach	# of Coho Redds		# of Adult Coho						Total Adults
				# of Live Adult Coho			# of Coho Carcasses			
		Definite	Possible	Male	Female	Unknown	Male	Female	Unknown	
12/2/04	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
12/15/04	2	2	0	4	2	1	0	3	1	11
	3	3	0	11	9	20	0	1	0	41
	4	15	1	8	14	0	0	0	0	22
	5	20	1	15	21	0	0	0	0	36
	6	15	1	14	14	1	1	0	0	30
	Totals	**55**	**3**	**52**	**60**	**22**	**1**	**4**	**1**	**140**
12/21/04	2	2	0	3	1	2	0	1	0	6
	3	2	6	7	10	18	1	2	2	39
	4	3	1	3	5	1	1	0	0	11
	5	1	1	3	8	1	1	1	0	14
	6	7	0	16	11	0	5	8	0	40
	Totals	**16**	**8**	**32**	**35**	**22**	**8**	**11**	**2**	**110**
1/6/05	2	1	2	11	2	1	0	0	0	14
	3	0	0	4	2	0	2	0	0	8
	4	2	0	2	3	1	1	1	2	10
	5	6	0	4	4	0	0	2	0	10
	6	10	0	4	8	0	3	3	1	19
	7	0	1	0	0	0	1	0	1	2
	Totals	**19**	**3**	**25**	**19**	**2**	**7**	**6**	**4**	**63**
1/18/05	2	1	0	0	0	0	3	0	2	5
	3	0	1	0	0	0	5	3	0	8
	4	0	2	0	0	0	1	0	1	2
	5	1	1	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	3	3
	Totals	**2**	**4**	**0**	**0**	**0**	**9**	**3**	**6**	**18**
2/9/05	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	1	0	1
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0
	Totals	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**
Yearly Total Redds		**92**	**18**							

The total density of spawners during the first peak of the run was 12 fish/km. Most live fish (43% of the total count) were observed in survey reaches five and six (Figure 3.2). The sex ratio from live fish observations was 41% male, 42% female, and 17% unknown.

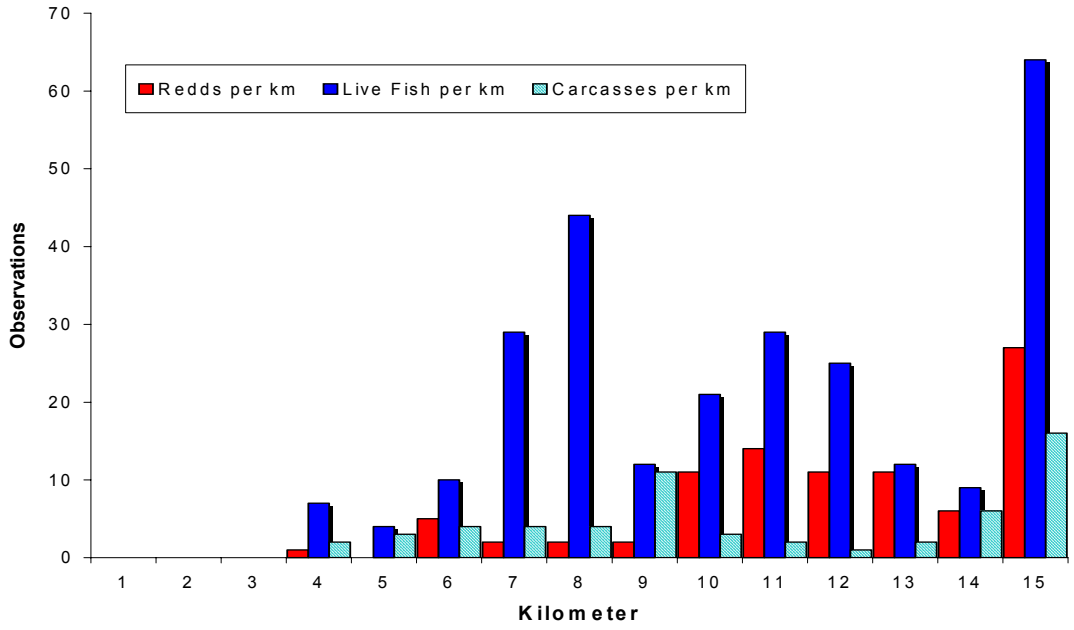

Figure 3.2. Live fish, carcass, and redd observations by kilometer during spawner year 2004-05 on the Olema Creek mainstem.

A total of 157 live coho were sighted in seven Olema Creek tributaries between 10 December 2004 and 1 February 2005. Almost all of the sightings (99%) occurred on John West Fork (Table 3.3). Two peaks were observed on the John West Fork run with the first peak of 48 fish occurring on December 10 and the second peak of 38 fish occurring on December 29. Only 6.4% (10 of 155) coho observed on John West Fork were counted within the 200 m section of stream below the State Route 1 culvert. One male and one female coho were observed on January 4 on lower Quarry Gulch. The sex ratio from live fish observations on Olema Creek tributaries was 53% male, 46% female, and 1% unknown.

Table 3.3 The number of live adult coho salmon, carcasses, and redds observed in John West Fork during 2004-05. Live fish observations do not represent the total number of spawning adults.

Survey Date	Reach	# of Coho Redds		# of Adult Coho						Total Adults
				# of Live Adult Coho			# of Coho Carcasses			
		Definite	Possible	Male	Female	Unknown	Male	Female	Unknown	
12/10/04	1	1	0	1	1	0	0	0	0	**2**
	2	16	1	26	19	1	0	0	0	**47**
	3	0	0	0	0	0	0	0	0	**0**
	Totals	**17**	**1**	**27**	**20**	**1**	**0**	**0**	**0**	**49**
12/16/04	1	0	0	0	0	0	0	0	0	**0**
	2	4	0	4	12	0	0	0	0	**16**
	3	0	0	0	0	0	0	0	0	**0**
	Totals	**4**	**0**	**4**	**12**	**0**	**0**	**0**	**0**	**16**
12/29/04	1	0	0	4	2	0	0	0	0	**6**
	2	5	0	20	12	0	0	0	0	**34**
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Totals	**5**	**0**	**24**	**14**	**0**	**0**	**0**	**0**	**40**
12/31/04	1	0	0	1	0	0	0	0	0	**1**
	2	5	0	19	11	1	0	0	0	**31**
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Totals	**5**	**0**	**20**	**11**	**1**	**0**	**0**	**0**	**32**
1/6/05	1	2	0	2	1	0	0	0	1	**4**
	2	12	0	9	13	0	3	1	1	**27**
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Totals	**14**	**0**	**11**	**14**	**0**	**3**	**1**	**2**	**31**
1/19/05	1	0	0	0	0	0	0	1	1	**2**
	2	0	0	0	0	0	0	2	0	**2**
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Totals	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**1**	**4**
2/1/05	1	0	0	0	0	0	0	0	0	**0**
	2	0	0	0	0	0	0	0	2	**2**
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**2**
Yearly Total Redds		**45**	**1**							

Reach 1: Confluence with Olema Creek to Hwy 1 culvert (0.2 km).
Reach 2: State Route 1 culvert to monument tag OL-1220 (1.8 km).
Reach 3: North Fork of John West Fork (0.4 km).

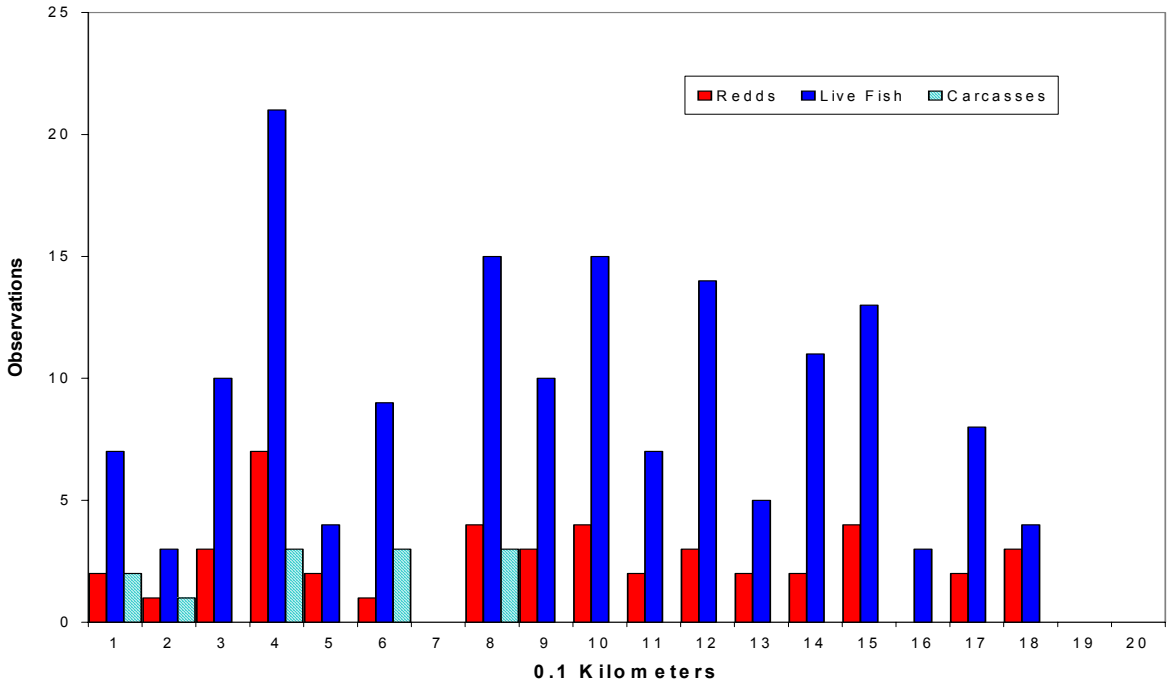

Figure 3.3. Live fish, carcass, and redd observations per 0.1 kilometer during spawner year 2004-05 on the John West Fork.

Steelhead

Although adult steelhead were not a focus of this study, observations of steelhead were recorded in the same fashion as live adult coho. Actual live adult steelhead counts are assumed to be much higher than the observed counts. The peak steelhead count on Olema Creek was observed on February 9 with a count of four adult steelhead. Steelhead were observed on surveys from January 6 to February 9. A total of two adult steelhead were observed during surveys performed on John West Fork Creek.

3.2.2 Carcasses

Coho

A total of 57 carcasses were found on the mainstem of Olema Creek during the 2004-05 season (Table 3.2). Six marked carcasses were recaptured during subsequent surveys. Most carcasses were recovered during the December 29 surveys; one week after the peak number of live fish were observed (Figure 3.1). Most carcasses were found in survey reach 6 (Figure 3.2). The carcass sex ratio was 40% male, 40% female and 19% unknown. Based on the distribution of fish sizes, it appeared that jacks (precocious two-year old males) composed 8% of the recovered coho. Scales were collected from all individuals and we plan to use them to separate two and three year old males. The mean fork length of male, female, and unknown sex carcasses was 68 cm (SD 5.6 cm), 66 cm (SD 3.4 cm), and 64 cm (SD 2.2 cm) respectively. The results of previous spawner surveys in the Olema Creek watershed suggested that jacks were typically less than 50 cm fork length. The mean length of males less than 50 cm fork length during the 2004-05 surveys was 45 cm (SD 3.5 cm).

A total of 14 carcasses were found on the five Olema Creek tributaries surveyed during the 2004-05 season (Table 3.3). No marked carcasses were recovered. All of the carcasses were recovered between January 4 and February 1, well after peak spawning had occurred. The highest recovery rate, 12 out of the 14 carcasses recovered, was observed in John West Fork where the majority of the tributary spawning also occurred. The tributary carcass sex ratio was 21% male, 36% female, and 43% unknown.

Steelhead
A total of four steelhead carcasses were recovered while performing surveys on Olema Creek. Two of the four carcasses were identified as male while the remaining two carcasses were not identified to sex. Three of the four carcasses were recovered on February 9. Lengths were only measured on two of the steelhead carcasses with one male measuring 78 cm and one steelhead of unknown sex measuring 28 cm. No steelhead carcasses were observed while surveying Olema Creek tributaries.

3.2.3 Redds

Redds are the best means of spatially representing use densities within the watershed. Within Olema Creek, monitoring efforts have allowed us to spatially represent redd density per 100 meter monument tag since 1997-98. Accumulation of these data show high use areas for spawning within the Olema and John West Fork watersheds.

Coho
A total of 92 redds were observed in the mainstem of Olema Creek during the 2004-05 season (Table 3.2). Redd construction was concentrated in survey reaches 4, 5, and 6 where 88% of the redds were observed. Most mainstem redds were constructed between December 15 and January 6. The total density of redds in the 11.6 km mainstem survey section was 7.9 redds/km. The mean surface area of all coho redds was 4.1 m^2 (SD 2.3). Observers made comments about features of the streambed that could not be positively identified as redds but were marked as possible redds instead. A total of 18 questionable redds were found. The mean surface area of 16 questionable coho redds was 2.5 m^2 (SD 1.4).

A total of 47 redds were observed in the five Olema Creek tributaries surveyed during the 2004-05 season (Table 3.2). Redd construction was concentrated in John West Fork where 96% of the tributary spawning occurred. Most of the redds were constructed betweeen December 10 and January 6. The density of redds in the 4.0 km Olema Creek tributaries surveyed was 11.75 redds/km. With John West Fork having the highest density of redds with 22.5 redds/km. Observers made comments of the streambed that could not be positively identified as redds but were marked as possible redds instead. A total of two questionable redds were found. Figure 3.4 shows a map representing coho spawning density for the 2004-05 season.

Steelhead
A total of fourteen steelhead redds were observed on Olema Creek with a peak redd count of seven redds observed on February 9. Steelhead redd observations were concentrated in the upper six kilometers of Olema Creek with eight of the fourteen redd observation located in survey reach 6. Redd construction on the mainstem of Olema Creek was observed from January 6 to February 9. A total of two steelhead redds and one questionable redd were observed on John West Fork Creek. The mean surface area for steelhead redds observed in the Olema Creek watershed was 1.2 m^2 (SD 0.8).

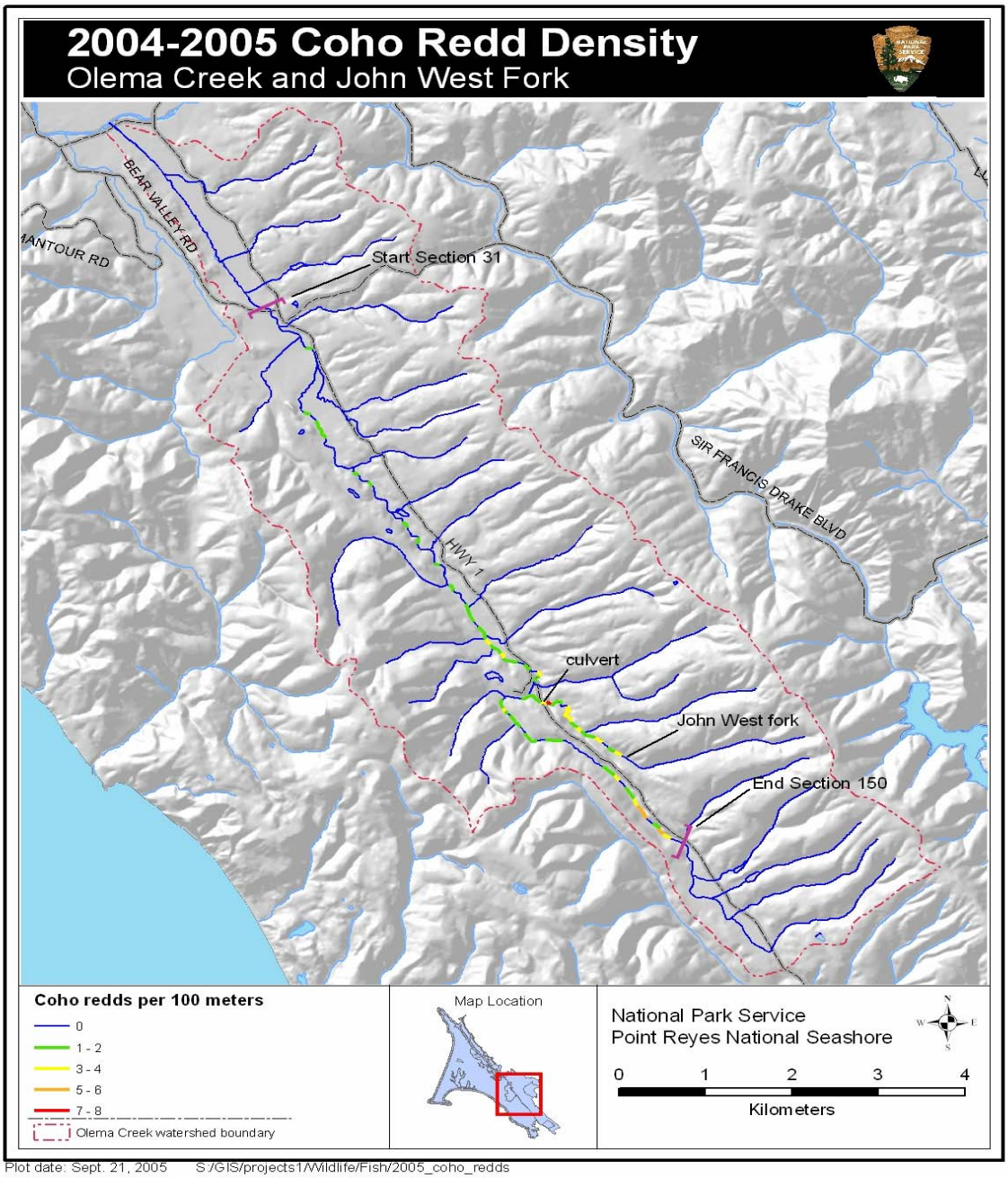

Figure 3.4. Coho redd density per 100 meters within Olema Creek and John West Fork, SY 2004-2005.

3.3 Escapement Estimates

3.3.1 Area Under the Curve and Peak Live Plus Cumulative Dead Indices

Area Under the Curve (AUC) estimates were generated for live fish on Olema Creek mainstem and John West Fork during 2004-05. Residence time (RT) and observer efficiency (OE) was not measured and potential AUC estimates were calculated based on values from published coho spawner studies. Eight studies were reviewed and had RT values ranging from eight to seventeen days. The most frequently

reported values were eleven and thirteen days. Two of the eight studies reported OE values between 69 and 76 percent (Solazzi et al.1984, Johnston et al. 1987). To consider a wider range observer efficiencies, AUC estimates were calculated for OE values between 50 and 100 percent.

Population estimates in the Olema Creek section ranged from 149 to 316 fish at 100% OE and 298 to 632 fish at 50% OE (Table 3.4). Estimates from the most commonly reported OE (70-80%) and RT (11-13 days) values ranged from 243 to 278 fish in Olema Creek.

Population estimates in the John West Fork survey section ranged from 60 to 127 fish at 100% OE and 120 to 255 fish at 50% OE (Table 3.5). Estimates from the most commonly reported OE (70-80%) and RT (11-13 days) values ranged from 98 to 132 fish in John West Fork.

Table 3.4 Area Under the Curve (AUC) population estimates for coho salmon adults in reaches 2-6 of Olema Creek during 2004-05. Potential estimates are given for various combinations of average residence time (spawning ground life) and observer efficiency. Neither residence time (RT) nor observer efficiency (OE) were estimated during the surveys. AUC Estimates derived from studies that measured coho RT and OE values are highlighted. Footnotes indicate published sources.

Residence Time (days)	Observer Efficiency					
	100%	90%	**80%[f]**	**70%[c]**	60%	50%
8[a]	316	351	395	452	527	632
9[b]	281	312	351	401	468	562
10[c]	253	281	316	361	422	506
11[d,e,f]	230	255	287	328	383	460
12	211	234	263	301	351	422
13[a,e,f,g]	195	216	243	278	324	389
14[g]	181	201	226	258	301	361
15[a]	169	187	211	241	281	337
16	158	176	198	226	263	316
17[a]	149	165	186	213	248	298

a/ Irvine et al. (1992)
b/ van der Berghe and Gross (1986)
c/ Flint (1984)
d/ Beidler and Nickelson (1980)
e/ Johnston et al. (1987): 69% observer efficiency
f/ Crone and Bond (1976)
g/ Koski (1966)
h/ Solazzi et al. (1984): 76% observer efficiency

Table 3.5 Area Under the Curve (AUC) population estimates for coho salmon adults in John West Fork during 2004-05. Potential estimates are given for various combinations of average residence time (spawning ground life) and observer efficiency. Neither residence time (RT) nor observer efficiency (OE) were estimated during the surveys. AUC Estimates derived from studies that measured coho RT and OE values are highlighted. Footnotes indicate published sources.

Residence Time (days)	Observer Efficiency					
	100%	90%	**80%[f]**	**70%[c]**	60%	50%
8[a]	127	141	159	182	212	255
9[b]	113	126	141	162	189	226
10[c]	102	113	127	146	170	204
11[d,e,f]	93	103	116	132	154	185
12	85	94	106	121	141	170
13[a,e,f,g]	78	87	98	112	131	157
14[g]	73	81	91	104	121	146
15[a]	68	75	85	97	113	136
16	64	71	80	91	106	127
17[a]	60	67	75	86	100	120

a/ Irvine et al. (1992)
b/ van der Berghe and Gross (1986)
c/ Flint (1984)
d/ Beidler and Nickelson (1980)
e/ Johnston et al. (1987): 69% observer efficiency
f/ Crone and Bond (1976)
g/ Koski (1966)
h/ Solazzi et al. (1984): 76% observer efficiency

3.3.2 Peak Live plus Cumulative Dead

Because coho return to spawn over a three-month period and residence time on the spawning grounds is variable, the same live fish are often double counted during repeated surveys. An index derived from adding the peak number of live fish observed during a single survey to the number of carcasses recovered prior to that date provides a minimum spawner estimate. The 2004-05 peak live plus cumulative dead (PLD) index was 184 on the Olema Creek mainstem and includes coho counts from December 15 and January 6. A PLD index of 86 coho was calculated for John West Fork and includes peak counts observed on December 10 and December 29.

4.0 2004-2005 REDWOOD CREEK ADULT COHO ESCAPEMENT RESULTS

Rainfall and moderate flows in early December were conducive to coho spawning while still allowing adequate visibility for good surveys. Peak spawning was observed in both mid December and early January, with 64 live coho observed on December 12 and 107 live coho observed on January 5. A total of 90 redds were distributed along the Redwood Creek starting at the Pacific Way bridge. Two major tributaries to Redwood Creek, Fern Creek and Kent Creek, were included in all survey results. Total survey distance was 9.4 kilometers.

4.1 Survey Timing and Environmental Conditions

Seven surveys were conducted in Redwood Creek between 11 December 2004 and 3 February 2005 (Table 4.1). The mean interval between surveys was eight days. Mean daily flow during the surveys ranged from 1.43 cfs on December 22 to 43.24 cfs on January 5. Average water clarity at the time of surveys ranged from 40 to 150 cm. Water clarity was greater than 50 cm in over 90% of the surveys. The onset of higher flows appeared to be related to live fish observations.

Table 4.1 Daily average flow, 7 day total rainfall per Julian week, 7 day average flow per Julian week, average water clarity, and the number of live coho observed in 2004-05 on the mainstem of Redwood Creek.

Julian Week	Survey Date	Survey Reaches	Calendar Day	Daily Average Flow on Survey Date (cfs)	7 Day Rainfall during Julian Week (in)	7 Day Average Flow During Julian Week (cfs)	Average Survey Water Clarity (cm)	Coho Redds	Coho Carcass	Live Coho
47					0	0.08				
48					0.39	N/A				
49					0	N/A				
50	11 Dec 04	1-3, 5	346	14.52	2.52	32.44	83	13	0	64
51	16 Dec 04	1-3	351	3.88	0.01	5.23	127	22	1	91
52	22 Dec 04	1-3, 5	357	1.43	0	1.46	137	14	12	38
1					5.11	74.44				
2	5 Jan 05	1-5	5	43.24	2.19	56.81	55	29	4	107
3	14 Jan 05	1-5	14	29.33	0.69	38.20	74	11	23	21
4					0	12.23				
5	25 Jan 05	1-5	25	4.53	0.73	6.28	125	1	15	1
6	3 Feb 05	1-5	28	3.03	0	3.97	123	0	6	0
7					0.15	1.13				

Reach 1: Pacific Way Bridge to the Kent Creek confluence in Mt. Tamalpais State Park (stream km 0.1 to 2.8)
Reach 2: Kent Creek confluence to Bridge 1 in Muir Woods (stream km 2.8 to 5.4)
Reach 3: Bridge 1 to 500m above Bridge 4 (stream km 5.4 to 7.4)
Reach 4: Kent Creek: confluence to water fall migration barrier (stream km 0 to1)
Reach 5: Fern Creek: confluence to steep cascade (stream km 0 to 1)

The Redwood Creek mainstem reaches 1 thru 3 were consistently sampled during each survey. Both Kent Creek and Fern Creek were surveyed when volunteer and staff turnout were high enough to cover both the mainstem and tributary reaches. Tributary reaches were surveyed on the same day as the mainstem reaches to eliminate the possibility of double counting.

Bankfull flow in Redwood Creek, (approximately 800 cfs) at the State Route 1 Bridge (Schanz et al. 1995), was not equaled exceeded during the 2004-05 spawner season. The peak discharge occurred on December 8, 2004 (463.53 cfs) and was approximately half the bankfull discharge. Total precipitation observed during the survey period was 11.79 in. Mean daily flows decreased from 31.2 cfs in December to 25.0 cfs in January and 23.0 cfs in February.

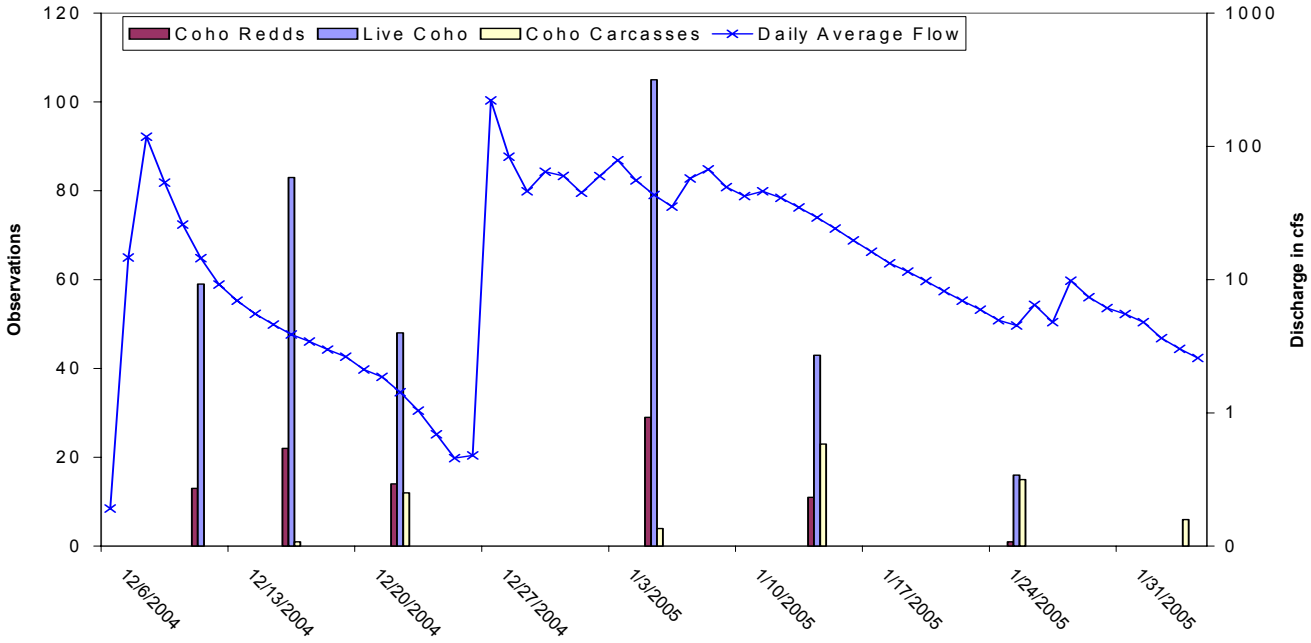

Figure 4.1. Representation of adult escapement survey results, including live fish, carcasses, and redds, observed during surveys in Water Year 2005. Discharge represents the average daily flow measured on the mainstem of Redwood Creek, at the State Route 1 bridge.

4.2 Live Fish, Carcass, and Redd Observations

4.2.1 Live Fish

Between 11 December 2004 and 3 February 2005, 322 live adult coho observations were made in the mainstem of Redwood Creek and major tributaries. Because the surveys were conducted frequently, many individual fish were counted more than once. Therefore, the total number of live fish observations is not an accurate estimator of the total spawning escapement. The first 64 fish observed on December 11 was also the first peak of the run (Figure 4.1). A second larger peak of 107 coho was observed on January 5, 26 days after the first peak. Assuming the longest coho residence time after stream entry is 21 days (longest observed in Olema Creek under low stress conditions was 20 days), it was determined that the live adult coho observed on December 11 were not recounted on the survey conducted on January 5.

Table 4. 2. The number of live adult coho salmon, carcasses, and redds observed in the mainstem of Redwood Creek during 2004-2005. Live fish observations do not represent the total number of spawning adults.

Survey Date	Reach	# of Coho Redds		# of Adult Coho						Total Adults
				# of Live Adult Coho			# of Coho Carcasses			
		Definite	Possible	Male	Female	Unknown	Male	Female	Unknown	
12/11/04	1	0	0	2	3	1	0	0	0	**6**
	2	4	1	11	10	3	0	0	0	**24**
	3	6	0	16	11	1	0	0	0	**28**
	Kent	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**N/A**
	Fern	3	0	2	4	0	0	0	0	**6**
	Totals	**13**	**1**	**31**	**28**	**5**	**0**	**0**	**0**	**64**
12/16/04	1	3	0	5	8	9	0	0	0	**22**
	2	9	1	23	22	0	0	0	1	**46**
	3	10	1	9	15	0	0	0	0	**24**
	Kent	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**N/A**
	Fern	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**N/A**
	Totals	**22**	**2**	**37**	**45**	**9**	**0**	**0**	**1**	**92**
12/22/04	1	1	0	2	1	0	1	2	0	**6**
	2	7	3	9	7	2	0	2	1	**21**
	3	5	1	10	7	0	0	4	0	**21**
	Kent	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**N/A**
	Fern	1	0	0	0	0	0	2	0	**2**
	Totals	**14**	**4**	**21**	**15**	**2**	**1**	**10**	**1**	**50**
1/5/05	1	0	0	5	4	1	0	0	0	**10**
	2	3	0	6	12	3	1	0	0	**22**
	3	19	1	28	24	1	0	0	2	**55**
	Kent	4	1	6	8	1	0	0	0	**15**
	Fern	3	0	2	6	0	0	1	0	**9**
	Totals	**29**	**2**	**47**	**54**	**6**	**1**	**1**	**2**	**111**
1/14/05	1	0	0	0	3	1	7	3	0	**14**
	2	1	1	1	5	0	1	6	1	**14**
	3	4	1	3	5	0	1	1	0	**10**
	Kent	4	0	0	0	0	0	1	0	**1**
	Fern	2	0	1	2	0	0	2	0	**5**
	Totals	**11**	**2**	**5**	**15**	**1**	**9**	**13**	**1**	**44**
1/25/05	1	0	0	0	1	0	3	6	4	**14**
	2	1	1	0	0	0	0	2	0	**2**
	3	0	0	0	0	0	0	0	0	**0**
	Kent	0	0	0	0	0	0	0	0	**0**
	Fern	0	0	0	0	0	0	0	0	**0**
	Totals	**1**	**1**	**0**	**1**	**0**	**3**	**8**	**4**	**16**
2/3/05	1	0	0	0	0	0	1	3	1	**5**
	2	0	0	0	0	0	0	1	0	**1**
	3	0	0	0	0	0	0	0	0	**0**
	Kent	0	0	0	0	0	0	0	0	**0**
	Fern	0	0	0	0	0	0	0	0	**0**
	Totals	**0**	**0**	**0**	**0**	**0**	**1**	**4**	**1**	**6**
Yearly Total Redds		**90**	**12**							

N/A – Reach was not surveyed

The total density of spawners during the second peak of the run was 11 fish/km. Most live fish (40% of the total count) were observed in survey reach three [stream km 5.4 to 7.4] (Figure 4.2). The sex ratio from live fish observations was 44% male, 49% female, and 7% unknown.

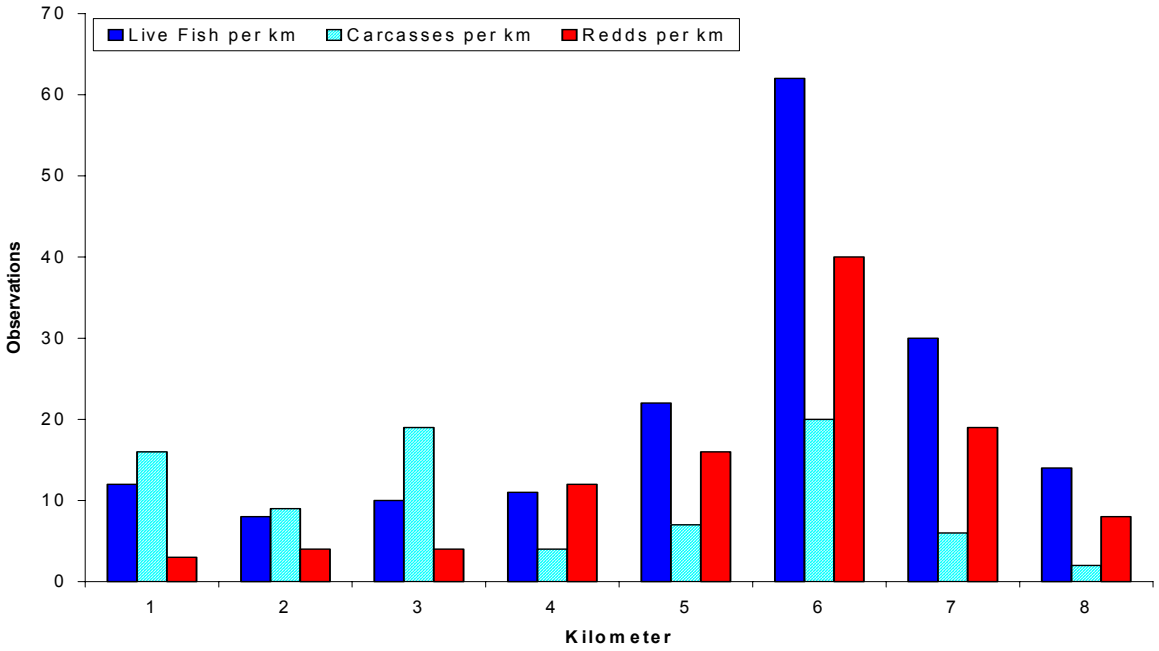

Figure 4.2. Live fish, carcass, and redd observations by kilometer during spawner year 2004-05 on the Redwood Creek mainstem.

4.2.2 Carcasses

A total of 61 carcasses were found on Redwood Creek during the 2004-05 season (Table 4.2). Six marked carcasses were recaptured during subsequent surveys. Most carcasses were recovered during the January 14 surveys; one week after the peak number of live fish were observed (Figure 4.1). Most carcasses were found in survey reach 1 [stream km 0.1 to 2.8] (Figure 4.2). The carcass sex ratio was 25% male, 59% female and 16% unknown. Scales were collected from all individuals and we plan to use them to separate two and three year old males. The mean fork length of male and female sex carcasses was 67 cm (SD 4.3 cm) and 63 cm (SD 4.8 cm) respectively. Only one carcass with a fork length of 70 cm was measured out of the ten unknown carcasses recovered. The results of previous spawner surveys in the Redwood Creek watershed suggested that jacks were typically less than 50 cm fork length. Only one male coho carcass was recovered that was considered a jack (precocious two-year old male) at 49 cm.

4.2.3 Redds

A total of 90 redds were observed in Redwood Creek during the 2004-05 season (Table 4.2), including 9 redds on Fern Creek, 8 redds on Kent Creek and 73 redds on the mainstem. Redd construction was concentrated in survey reach 3 [stream km 5.4 to 7.4] where 49% of the redds were observed. Most mainstem redds were constructed between December 11 and January 5. The total density of redds in the 9.4 km mainstem survey section was 9.6 redds/km. The mean surface area of all coho redds was 3.2 m^2 (SD 1.8). Observers made comments about features of the streambed that could not be positively identified as redds but were marked as possible redds instead. A total of 12 questionable redds were found. The mean surface area of the12 questionable coho redds was 2.9 m^2 (SD 1.9).

4.3 Escapement Estimates

4.3.1 Area Under the Curve and Peak Live Plus Cumulative Dead Indices

Area Under the Curve (AUC) estimates were generated for live fish on Redwood Creek during 2004-05. Residence time (RT) and observer efficiency (OE) was not measured and potential AUC estimates were calculated based on values from published coho spawner studies. Eight studies were reviewed and had RT values ranging from eight to seventeen days. The most frequently reported values were eleven and thirteen days. Two of the eight studies reported OE values between 69 and 76 percent (Solazzi et al.1984, Johnston et al. 1987). To consider a wider range observer efficiencies, AUC estimates were calculated for OE values between 50 and 100 percent.

Population estimates in the Redwood Creek section ranged from 169 to 359 fish at 100% OE and 338 to 718 fish at 50% OE (Table 4.4). Estimates from the most commonly reported OE (70-80%) and RT (11-13 days) values ranged from 276 to 373 fish in Redwood Creek.

Table 4.3 Area Under the Curve (AUC) population estimates for coho salmon adults in Redwood Creek during 2004-05. Potential estimates are given for various combinations of average residence time (spawning ground life) and observer efficiency. Neither residence time (RT) nor observer efficiency (OE) were estimated during the surveys. AUC Estimates derived from studies that measured coho RT and OE values are highlighted. Footnotes indicate published sources.

Residence Time (days)	Observer Efficiency					
	100%	90%	**80%[f]**	**70%[c]**	60%	50%
8[a]	359	399	449	513	599	718
9[b]	319	355	399	456	532	639
10[c]	287	319	359	411	479	575
11[d,e,f]	261	290	327	373	435	522
12	239	266	299	342	399	479
13[a,e,f,g]	221	246	276	316	368	442
14[g]	205	228	257	293	342	411
15[a]	192	213	239	274	319	383
16	180	200	224	257	299	359
17[a]	169	188	211	241	282	338

a/ Irvine et al. (1992)
b/ van der Berghe and Gross (1986)
c/ Flint (1984)
d/ Beidler and Nickelson (1980)
e/ Johnston et al. (1987): 69% observer efficiency
f/ Crone and Bond (1976)
g/ Koski (1966)
h/ Solazzi et al. (1984): 76% observer efficiency

4.3.2 Peak Live plus Cumulative Dead

Because coho return to spawn over a three-month period and residence time on the spawning grounds is variable, the same live fish are often double counted during repeated surveys. An index derived from adding the peak number of live fish observed during a single survey to the number of carcasses recovered

prior to that date provides a minimum spawner estimate. The 2004-05 peak live plus cumulative dead (PLD) index was 171 on the Redwood Creek and includes coho counts from December 11 and January 5.

5.0 2004-2005 PINE GULCH CREEK ADULT COHO ESCAPEMENT RESULTS

Rainfall and moderate flows in early December were conducive to coho spawning while still allowing adequate visibility for good surveys. Coho spawning was observed in both mid-December and early January, with one live female coho observed on December 14 and two live coho (one male and one female) observed on January 10. A total of three coho redds were distributed along Pine Gulch Creek starting at the Olema-Bolinas Road bridge.

5.1 Survey Timing and Environmental Conditions

Five surveys were conducted in Pine Gulch Creek between 1 December 2004 and 10 February 2005 (Table 5.1). The mean interval between surveys was eighteen days. Mean daily flow during the surveys ranged from 1.11 cfs on December 1 to 41.47 cfs on January 10. Average water clarity at the time of surveys ranged from 60 to 105 cm. Water clarity was greater than 50 cm in all of the surveys. The onset of higher flows appeared to be related to live fish observations.

Table 5.1 Daily average flow, 7 day total rainfall per Julian week, 7 day average flow per Julian week, average water clarity, and the number of live coho observed in 2004-05 on the mainstem of Pine Gulch Creek.

Julian Week	Survey Date	Survey Reaches	Calendar Day	Daily Average Flow on Survey Date (cfs)	7 Day Rainfall during Julian Week (in)	7 Day Average Flow During Julian Week (cfs)	Average Survey Water Clarity (cm)	Coho Redds	Coho Carcass	Live Coho
47					0	1.21				
48					0.53	1.42				
49	1 Dec 04	1	335	1.11	0	1.17		0	0	0
50					3.54	3.85				
51	14 Dec 04	1-2	348	2.44	0.04	2.41	100	2	0	1
52					0	2.68				
1					5.32	84.38				
2					2.53	52.90				
3	10 Jan 05	1-2	10	41.47	0.54	38.50	60	0	0	2
4	20 Jan 05	1-2	20	10.39	0	12.00	105	0	0	0
5					1	10.05				
6					0	7.90				
7	10 Feb 05	1-2	41	5.28	0.17	5.56	105	0	0	0

Reach 1: Olema-Bolinas Road Bridge to the Copper Mine Gulch Confluence (6.0 km)
Reach 2: Copper Mine Gulch Confluence to upstream of Teixeira to approximately monument marker 100 (3.5 km).

Pine Gulch mainstem reaches 1 and 2 were consistently sampled during each survey except for the first preliminary survey, which was performed in reach 1 to verify that no spawning activity had occurred before the onset of higher flows. No tributary reaches were surveyed due to rough terrain and the lack of available staff.

5.2 Live Fish, Carcass, and Redd Observations

Between 14 December 2004 and 10 January 2005, three live adult coho were observed in the mainstem of Pine Gulch Creek (Table 5.2). Because the surveys were conducted infrequently, individual fish observations can be considered independent observations and not repeated counts. The female adult coho observed on December 14 was observed holding on a newly formed redd. The male and female adult coho

observed on January 10 were observed as a spawning pair constructing a redd. Although adult steelhead were not a focus of this monitoring program, observations of steelhead were recorded in the same fashion as live adult coho. A total of four adult steelhead were observed between January 20 and February 10, 2005. No coho or steelhead carcasses were recovered while conducting spawner surveys on Pine Gulch Creek.

A total of three coho redds were observed on Pine Gulch Creek between December 14 and January 10 (Table 5.2). Only two of the three redds observed were measured for surface area (6.4 m^2 and 2.4 m^2). Observers made comments of the streambed that could not be positively identified as redds but were marked as possible redds instead. A total of four questionable redds were found. A total of 27 steelhead redds were observed on Pine Gulch Creek during the 2004-05 season. The mean surface area for all steelhead redds was 1.4 m^2 (SD 1.0). Steelhead redd construction was observed from January 20 to February 10. Three questionable steelhead redds were also observed in reach 1.

Table 5.2 The number of live adult coho salmon, carcasses, and redds observed in the mainstem of Pine Gulch Creek during 2004-2005. Live fish observations do not represent the total number of spawning adults.

Survey Date	Reach	# of Coho Redds		# of Adult Coho						Total Adults
				# of Live Adult Coho			# of Coho Carcasses			
		Definite	Possible	Male	Female	Unknown	Male	Female	Unknown	
12/01/04	1	0	0	0	0	0	0	0	0	**0**
	Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
12/14/04	1	0	0	0	0	0	0	0	0	**0**
	2	1	0	0	1	0	0	0	0	**1**
	Totals	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**1**
1/10/05	1	2	0	1	1	0	0	0	0	**2**
	2	0	0	0	0	0	0	0	0	**0**
	Totals	**2**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**2**
1/20/05	1	0	2	0	0	0	0	0	0	**0**
	2	0	2	0	0	0	0	0	0	**0**
	Totals	**0**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2/10/05	1	0	0	0	0	0	0	0	0	**0**
	2	0	0	0	0	0	0	0	0	**0**
	Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Yearly Redd Totals		**3**	**4**							

6.0 2004-2005 CHEDA CREEK ADULT COHO ESCAPEMENT RESULTS

Annual documentation of spawner surveys in the Lagunitas Creek watershed are produced through the Marin Municipal Water District. The 2004-2005 spawner survey report (MMWD 2005) documented a total of 496 coho redds and 1,830 live coho were observed during the spawner surveys in Lagunitas Creek, San Geronimo Creek, Devil's Gulch, Cheda Creek and the smaller tributaries to Lagunitas and San Geronimo Creeks (excluding Olema Creek). This represented a record number of fish and redds over the ten years of spawner surveys. A total of 383 redds and 949 live fish were recorded in SY 2003-04. The 2001-02 spawning survey (representing the last generation of this year class) recorded 286 redds and 735 live coho (MMWD 2001).

Rainfall and moderate flows in early December were conducive to coho spawning while still allowing adequate visibility for good surveys. Coho spawning was observed in both mid-December and early January, with a peak live count of 10 adult coho observed on December 10 and second peak of 7 live coho observed on January 4. A total of six coho redds were distributed along Cheda Creek starting at the confluence with Lagunitas Creek. For the first time, a coho adult and redd were observed upstream of the fish passage restoration project site (completed in 2000) at the main ranch location.

6.1 Survey Timing and Environmental Conditions

Four surveys were conducted in Cheda Creek between 10 December 2004 and 13 January 2005 (Table 6.1). The mean interval between surveys was eleven days. Average water clarity at the time of surveys ranged from 35 to 75 cm. Water clarity was greater than 50 cm in 25% of the surveys.

The Cheda Creek survey reaches were consistently sampled during each survey with approximately 1.2 km of stream surveyed. One section of stream in reach 1 is excluded from the survey due to rough terrain and a poison oak thicket. This section is approximately 100 meters long and is directly downstream of the fish passage structure.

6.2 Live Fish, Carcass, and Redd Observations

Between 10 December 2004 and 13 January 2005, 23 live adult coho were observed in Cheda Creek (Table 6.1). Because the surveys were conducted frequently, individual fish observations may include repeated counts. Therefore, the total number of live fish observations is not an accurate estimator of the total spawning escapement. The first 10 fish observed on December 10 was also the first peak of the run. A second smaller peak was observed on January 4, 26 days later, with seven fish observed. Assuming the longest coho residence time after stream entry is 21 days (longest observed in Olema Creek under low stress conditions was 20 days), it was determined that the live adult coho observed on December 10 were not recounted on the survey conducted on January 4.

One female adult coho was observed holding on a redd on January 4 upstream of the fish passage structure constructed in 2000. This is the first coho spawning observed upstream of the fish passage restoration site. No live steelhead adults or steelhead carcasses were observed while performing coho spawner surveys. One male coho carcass measuring 64 cm was recovered on January 13.

A total of six coho redds were observed on Cheda Creek between December 10 and January 13 (Table 6.1). The mean surface area of all coho redds was 2.9 m^2 (SD 1.1). One steelhead redd was observed on Cheda Creek on January 13 with a surface area of 1.5 m^2. Observers made comments of the streambed that could not be positively identified as redds but were marked as possible redds instead. One questionable steelhead redd was also observed in reach one.

Table 6.1 The number of live adult coho salmon, carcasses, and redds observed in Cheda Creek during 2004-2005. Live fish observations do not represent the total number of spawning adults.

Survey Date	Reach	# of Coho Redds		# of Adult Coho						Total Adults
				# of Live Adult Coho			# of Coho Carcasses			
		Definite	Possible	Male	Female	Unknown	Male	Female	Unknown	
12/10/04	1	3	0	6	4	0	0	0	0	**10**
	2	0	0	0	0	0	0	0	0	**0**
	Total	**3**	**0**	**6**	**4**	**0**	**0**	**0**	**0**	**10**
12/31/04	1	0	0	2	1	2	0	0	0	**5**
	2	0	0	0	0	0	0	0	0	**0**
	Total	**0**	**0**	**2**	**1**	**2**	**0**	**0**	**0**	**5**
1/4/05	1	1	0	3	3	0	0	0	0	**6**
	2	2	0	0	1	0	0	0	0	**1**
	Total	**3**	**0**	**3**	**4**	**0**	**0**	**0**	**0**	**7**
1/13/05	1	0	0	0	1	0	1	0	0	**2**
	2	0	0	0	0	0	0	0	0	**0**
	Total	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**2**
Yearly Redd Totals		**6**	**0**							

Reach 1: Confluence with Lagunitas Creek to 0.8 km upstream.
Reach 2: Upstream extent of the fish passage restoration site at 0.8 km upstream to 1.3 km upstream.

7.0 WATERSHED SUMMARY OF ADULT ESCAPEMENT SURVEYS

7.1 Olema Creek

Review of the eight years of escapement monitoring information on Olema Creek shows that run timing is highly dependent on the rainfall-runoff condition within the watershed (Table 7.1). Unlike Lagunitas Creek, Olema Creek is an unregulated stream. This makes conditions far more vulnerable to the variable environmental conditions that limit flows in the winter season. Adult coho salmon runs within the CCCESU are compressed into a very short window, with upstream migration coinciding with brief peak winter discharges, typically peaking in January (Weitkamp et.al. 1995). Freshwater residence time is short (typically less than 2 weeks), though the NPS program has documented some individuals spending up to 20 days in the freshwater under ideal conditions.

7.1.1 Survey Timing and Environmental Conditions

Our monitoring efforts have shown some years where flows necessary to allow entry into the watershed did not occur until mid-January. In those years, fish were stacked in the estuary waiting for Olema Creek attraction flows. In other years, rains in November have resulted in flows that would allow coho access to the watershed. Even when the early entry opportunity has occurred in November, few coho have been observed. For the most part, peak of spawning within Olema Creek is between mid-December and mid-January. Typically the peak count will follow a large flow event, encouraging fish that were waiting at the mouth of the watershed to enter and spawn. Table 7.2 shows the approximate entry and spawning window monitored for coho salmon between spawner year (SY) 1997-98 and SY 2003-04.

Table 7.1 Monthly environmental and physical factors monitored in Olema Creek for spawner years 1997-98 through 2004-05.

Spawner Year	Total Rainfall (in)				Mean Daily Discharge (cfs)				Max Daily Discharge (cfs)			
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
1997-1998	10.32	3.47	16.49	24.68	24.2	28.5	168.7	372.6	207.6	93.5	663	1339.6
1998-1999	7.48	2.21	7.66	15.61	9.6	23.5	52.8	98.2	140	132	218	311
1999-2000	5.2	0.99	7.15	12.77	2.1	1.9	37.8	120	4.5	3.7	278	777
2000-2001	1.54	1.31	6.45	8.07	1.8	2.4	30.1	83.1	2.6	4	193.4	423.1
2001-2002	9.81	15.03	5.08	3.55	21.7	103.1	103.5	45.4	169.4	373.7	840.2	165.3
2002-2003	3.3	17.33	3.75	2.34	2.3	117	65.1	21.8	5.4	383.9	177.3	110.3
2003-2004	2.71	12.14	5.13	7.68	1.9	109.1	59.0	46.0	2.9	1018.3	266.0	135.0
2004-2005	0.65	10.13	4.85	5.33	1.1	59.1	48.9	44.7	1.5	705.8	98.8	157.6

Conditions where Olema Creek run timing was far different than that observed in Lagunitas Creek occurred in 1999-2000 and 2000-2001, where Olema entry flow was delayed by 2 months, and in 2002-2003 and 2003-2004, where Olema entry flows were delayed by one month. Surveys indicated that coho did indeed wait to enter the watershed, and that once in the stream, spawning occurred almost immediately. This behavior has raised an important question regarding how populations maintain themselves in a watershed with regulated and unregulated channels. The escapement and timing within the unregulated Olema Creek watershed may be affected negatively by outside influences.

Under State Water Resources Control Board Order 95-17, the Marin Municipal Water District is required to release winter attraction flows (>25 cfs for three days) through Lagunitas Creek prior to December 1 each year. Such releases in a low-flow year could attract fish that would otherwise move up Olema Creek. In addition, the estuary at the mouth of Olema Creek is highly constrained by levees associated with Sir Francis Drake Blvd and the Giacomini Dairy. For fish that do remain near the mouth of Olema Creek for an attraction flow, the shallow, exposed pools may make adult salmon susceptible to both temperature

effects and predation. Each of these factors may play into the escapement in years where natural rainfall runoff conditions are temporally distinct from the winter reservoir releases.

Table 7.2 Coho salmon run timing, average daily discharge by month, and Olema Creek Peak Live plus Cumulative Dead (PLD), total carcasses and redds documented in the surveys for spawner years 1997-98 through 2004-05 within the Olema Creek mainstem.

Spawner Year (SY)	Run Timing				Average Daily Discharge (cfs)				Olema Creek PLD			
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds
1997-1998					24.2	28.5	168.7	372.6	13.4	88	39	126
1998-1999					9.6	23.5	52.8	98.2	11.6	42[a]	13	42
1999-2000[b]					2.1	1.9	37.8	120	7.2	9	9	10
2000-2001					1.8	2.4	30.1	83.1	11.6	103	65	86
2001-2002					21.7	103.1	103.5	45.4	11.6	90[c]	28	58
2002-2003[b]					2.3	117	65.1	21.8	11.6	20	17	5
2003-2004					1.9	109.1	59.0	46.0	11.6	138[d]	34	88
2004-2005					1.1	59.1	48.9	44.7	11.6	184[d]	63	92

a/ Includes two peaks, 7 weeks apart.
b/ Surveys missed peak numbers.
c/ Includes two peaks, 4 weeks apart
d/ Includes two peaks, 3 weeks apart

7.1.2 Watershed Escapement History and Estimates

Escapement estimates for adults in Olema Creek have been made using both the Peak Live plus cumulative Dead (PLD) and Area Under the Curve (AUC) method. In years where persistent high flows resulted in a low number of surveys, both methods likely under-represented the true escapement number. The AUC method is dependent on two variables, observer efficiency (OE) and fish residence time (RT) in the freshwater following entry. In years where flows were high, both OE and RT were assumed to be lower than normal.

Annual escapement estimates for Olema Creek show a range of 9-184 using the PLD index. Estimates using the AUC method are much higher with estimates reaching beyond 300 adults in some years. The Olema Creek escapement estimates represent 20-40% of the total escapement estimated for the Lagunitas Creek watershed.

PLD Index Results

The PLD dataset for adult escapement within Olema Creek includes 11 years of survey information. It should be noted that prior to SY 1997-98, redds and carcasses were not consistently counted. Olema Creek mainstem (Table 7.3) and the John West Fork tributary (JWF) (Table 7.4) are reported separately. PLD estimates have ranged from 9 to 184 for the mainstem and 8-86 for JWF. The John West Fork tributary has been the focus of extensive restoration and monitoring, and is often used as the proxy of conditions in the mainstem. In the SY 1999-00 and SY 2002-03, PLD estimates and live fish observations on the two kilometer survey area of JWF exceeded those of the 13 kilometer mainstem. The results of SY 1999-00 and SY 2002-03 are not considered representative of actual mainstem escapement due to poor survey conditions in the Olema mainstem during these years.

Table 7.3 Coho Salmon Spawning Survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for the Olema Creek mainstem.

Year	Number of Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
1994/95	3	13.4	53	1	9	Tomales Bay Association (TBA)
1995/96	2	13.4	106	37	N.A.	Manning 1999
1996/97	2	15.6	174	16	N.A.	Manning 1999
1997/98	8	13.4	88	39	126	Manning 1999
1998/99	6	11.6	42[a]	13	42	NPS-PRNS
1999/00[b]	2	7.2	9	9	10	NPS-PRNS
2000/01	4	11.6	103	65	86	NPS-PRNS
2001/02	4	11.6	90[c]	28	58	NPS-PRNS
2002/03 [b]	4	11.6	20	17	5	NPS-PRNS
2003/04	6	11.6	138 [d]	34	88	NPS-PRNS
2004/05	6	11.6	184 [d]	63	92	NPS-PRNS

a/ Includes two peaks, 7 weeks apart.
b/ Surveys missed peak numbers.
c/ Includes two peaks, 4 weeks apart
d/ Includes two peaks, 3 weeks apart
N.A. = not available.

Table 7.4 Coho Salmon Spawning Survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for the John West Fork of Olema Creek.

Year	Number of Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
1995/96	N.A.	<1.0	8[a]	N.A.	N.A.	NPS-PRNS
1996/97	N.A.	N.A.	N.A.	N.A.	N.A.	NPS-PRNS
1997/98	5	1.3	12	0	7	NPS-PRNS
1998/99	2	1.2	9	0	1	NPS-PRNS
1999/00[b]	3	1.1	18	0	7	NPS-PRNS
2000/01	4	1.9	58	30	48	NPS-PRNS
2001/02	6	1.9	20	5	31	NPS-PRNS
2002/03	7	1.3	27[c]	0	12	NPS-PRNS
2003/04	6	2.4	41	7	21	NPS-PRNS
2004/05	7	2.4	86 [d]	12	45	NPS-PRNS

a/ Includes live fish only, no carcass data.
b/ Surveys missed peak numbers.
c/ Includes two peaks, 4 weeks apart
d/ Includes two peaks, 3 weeks apart
N.A. = not available.

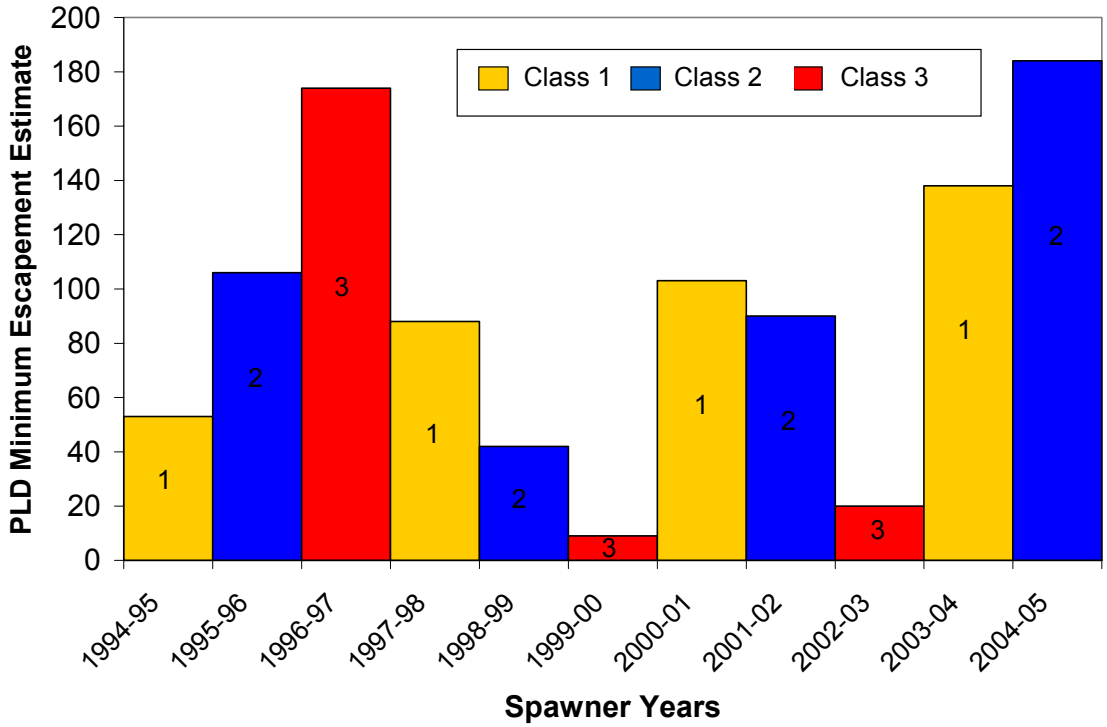

Figure 7.1 Olema Creek Coho Salmon PLD Index Escapement results winter 1994-1995 through winter 2004-2005.

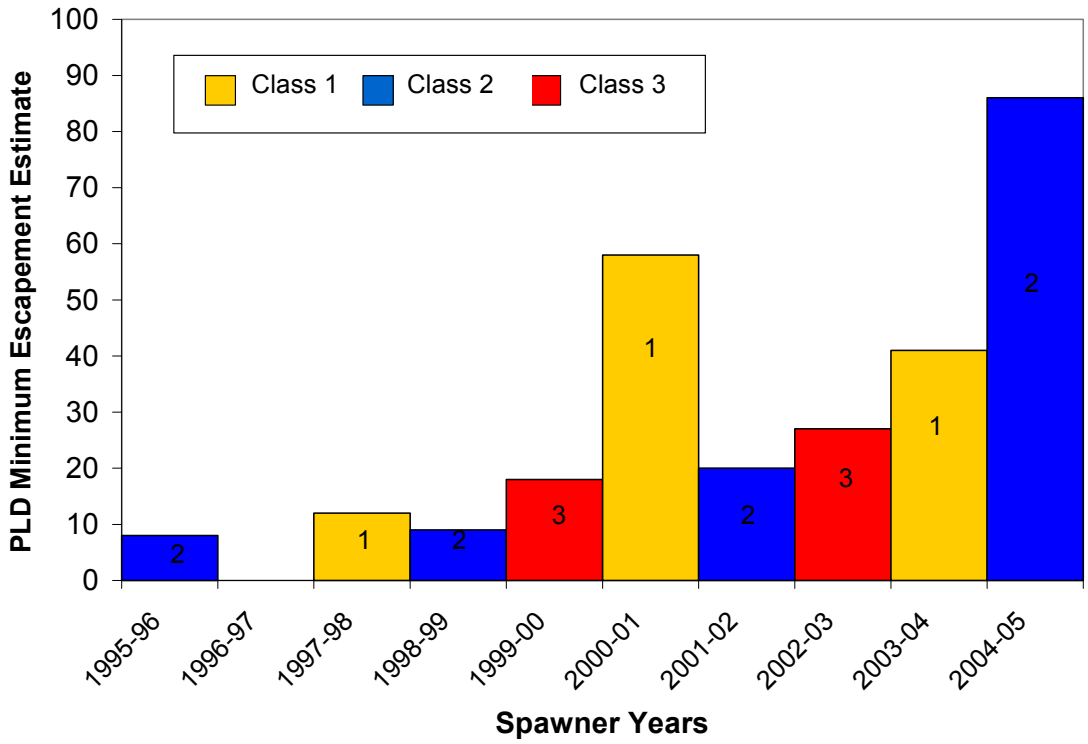

Figure 7.2 John West Fork Creek Coho Salmon PLD Index Escapement results winter 1995-1996 through winter 2004-2005.

AUC Escapement Estimate

The PLD index is assumed to be a minimum count of fish within a watershed, as it is based on actual observations. The NPS has also used the AUC method to estimate adult escapement within Olema Creek (Table 7.5) and the John West Fork tributary (Table 7.6). This method requires more consistent surveys and allows for an estimate of survey quality (observer efficiency) and the residence time of fish within the watershed. This method will tend to overestimate fish numbers where there are multiple peaks of fish or if there is a large interval between surveys. Only live fish are calculated using this technique.

Table 7.5 Coho salmon spawning survey Area Under the Curve (AUC) estimates for Olema Creek, 1997-98 through 2004-05.

Year	Number of Surveys	Date of Entry	Mean Survey interval (days)	Survey Reaches	Survey Area (km)	AUC Range 100% OE [1]	AUC Range 50% OE [2]	AUC Range for OE & RT reported in literature	AUC for locally observed conditions	OLM Mainstem PLD
1997/98	7	15 Nov 97	7.9	2-4	4.5	56-118	112-236	91-123	Same	88
1998/99	5	19 Nov 98	12.1	2-6	11.6	35-74	69-148	57-77	Same	42[d]
1999/00	2	18 Jan 00	N.A.			N.A.	N.A.	N.A.	N.A.	9
2000/01	2	10 Jan 01	7.3	2-6	11.6	75-159	149-317	122-165	101-132[a]	103
2001/02	3	24 Nov 01	12.3	2-6	11.6	105-224	210-447	172-232	186-256[b]	90[e]
2002/03	2	13 Dec 02	N.A.			N.A.	N.A.	N.A.	N.A.	20
2003/04	4	14 Dec 03	11.8	2-6	11.6	138-293	275-585	225-304	217-293[c]	138[f]
2004/05	6	15 Dec 04	10.8	2-6	11.6	149-316	298-632	243-328	Same	184[f]

N.A. – Survey data for mainstem not adequate to develop AUC estimate.
a- OE 80-90% / RT 12-14 days
b- OE 70-80% / RT 10-12 days
c- OE 80-90% / RT 10-12 days
d- Surveys missed peak numbers.
e- Includes two peaks, 4 weeks apart
f- Includes two peaks, 3 weeks apart

Table 7.6 Coho salmon spawning survey Area Under the Curve (AUC) estimates for John West Fork, 1997-98 through 2004-05.

Year	Number of Surveys	Date of Entry	Mean Survey interval (days)	Reaches	Survey Area (km)	AUC Range 100% OE	AUC Range 50% OE	AUC Range for OE & RT reported in literature	AUC for locally observed conditions	John West Fork PLD
1997/98	NA	15 Nov 97	7.9							12
1998/99	NA	19 Nov 98	12.1							9
1999/00	3	18 Jan 00	4.7	1-2	1.1	7-15	14-30	12-16	16-22[a]	18
2000/01	4	10 Jan 01	9.4	1-2	1.9	42-90	85-180	69-94	57-75[b]	58
2001/02	6	24 Nov 01	7.4	1-2	1.9	25-53	50-107	41-55	44-61[c]	20
2002/03	6	13 Dec 02	6.9	1-2	1.3	14-30	28-61	23-31	Same	27[d]
2003/04	4	14 Dec 03	9.6	1-3*	2.4	30-64	60-129	49-67	Same	41
2004/05	7	10 Dec 04	8.8	1-2	1.8	60-127	120-255	98-132	Same	86

NA – Survey data for mainstem not adequate to develop AUC estimate.
a- OE 60-70% / RT 9-11 days
b- OE 80-90% / RT 12-14 days
c- OE 70-80% / RT 10-12 days
d- Includes two peaks, 4 weeks apart
e- Includes two peaks, 3 weeks apart
* - Reach 3 is North Fork tributary of John West Fork

7.1.3 Live Fish, Carcass, and Redd Observations

Information on live fish, carcasses, and redds are collected during each field survey. Sex ratios for live fish and carcasses are reported for each spawner year in Table 7.7. While live fish lengths are estimated (length to nearest 5cm), carcasses are handled to definitively determine sex, spawn success, fork length (FL), and to collect a genetics sample. The results of carcass measurements show that males are generally between 65-75 cm, with females averaging 57-67 cm and jacks (two year old males) averaging from 37-47 cm.

Table 7.7 Sex ratios of live coho and carcasses, and size observations of carcasses within Olema Creek.

		Live Coho		Carcasses			
		#		#		mean FL	FL SD
1997-98	M	71	30%	16	47%	63.9 (n=15)	5.1
	F	95	40%	12	35%	59.1 (n=11)	3.1
	J	42	18%	5	15%	45.4 (n=5)	4.3
	Unk	29	12%	1	3%		
	All	237	100%	34	100%		
1998-99	M	11	21%	4	31%	64.0 (n=2)	1.4
	F	25	47%	4	31%	61.0 (n=4)	3.4
	J	7	13%	3	23%	45.7 (n=3)	2.1
	Unk	10	19%	2	15%		
	All	53	100%	13	100%		
1999-00	M	1	50%	2	22%	65 (n=1)	
	F	1	50%	6	67%	58.3 (n=6)	8.2
	J	0	0%	1	11%		
	Unk	0	0%	0	0%		
	All	2	100%	9	100%		
2000-01	M	42	34%	22	34%	66.3 (n=22)	6.4
	F	61	50%	35	54%	65.4 (n=35)	4.7
	J	17	14%	8	12%	44.9 (n=8)	2.0
	Unk	3	2%	0	0%		
	All	123	100%	65	100%		
2001-02	M	38	40%	8	30%	72.5 (n=6)	2.7
	F	46	48%	12	44%	66.7 (n=6)	6.3
	J	6	6%	1	4%	45 (n=1)	
	Unk	5	5%	6	22%		
	All	95	100%	27	100%		
2002-03	M	0	0%	7	41%	68.8 (n=4)	6.3
	F	2	67%	0	0%		
	J	1	33%	2	12%	37.5 (n=2)	3.5
	Unk	0	0%	8	47%	57.5 (n=4)	14.4
	All	3	100%	17	100%		
2003-04	M	37	26%	7	21%	74.3 (n=4)	1.5
	F	68	48%	11	32%	66.3 (n=10)	6.3
	J	31	22%	6	18%	45.2 (n=6)	2.0
	Unk	5	4%	10	29%	60.0 (n=4)	12.2
	All	141	100%	34	100%		
2004-05	M	72	27%	24	38%	68.7 (n=14)	6.1
	F	114	42%	25	40%	65.7 (n=20)	3.3
	J	72	14%	1	1%	47.0 (n=1)	
	Unk	46	17%	13	21%	59.0 (n=4)	11.5
	All	269	100%	63			

7.1.4 Olema Creek Watershed Summary

The emerging picture from 11 winters of coho spawner surveys on Olema Creek (Figure 7.1) reveals the presence of two strong year classes (year class 1 and 2) and one weak year class (year class 3). Previously, year class 3 was probably the strongest of the three, with a PLD index of 180 during the 1996-97 spawning run. However, the resulting cohort likely suffered high mortality during the last large-scale El Nino Southern Oscillation (ENSO) event in 1997-98. This event caused high flows during the winter of 1997-98 which may have resulted in low overwinter survival for the juvenile coho. Results of adult escapement and summer juvenile density monitoring indicate that the overwintering year class during the height of El Nino was the most heavily impacted and marks the shift of that cohort to the weakest year class. Although low spawner counts for the last two runs of this year class may be due in part to poor survey conditions during the winters of 1999-2000 and 2002-03, juvenile density observations support the notion that this became, and now remains the weakest year class.

On John West Fork Creek, 10 winters of coho spawning surveys (Figure 7.2) has revealed a much different scenario than observed on the Olema Creek mainstem. Results indicate a dramatic increase in coho spawners above the State Route 1 culvert (MP 22.67) since the completion of the culvert modification to improve fish passage. In spawner year 2003-04 a slight decrease was observed in year class 1. Both year class 2 and 3 continue to increase in numbers of returning adults with each successive generation. In the 1999-2000 and 2002-2003 spawning years, JWF counts exceeded mainstem results, likely due in part to lower flows and better survey conditions on the tributary.

7.2 Redwood Creek

7.2.1 Survey Timing and Environmental Conditions

Review of the eleven years of escapement monitoring information on Redwood Creek indicates that run timing is highly dependent on the rainfall-runoff condition within the watershed (Table 7.8). Redwood Creek is an unregulated stream with variable environmental conditions that limit flows in the winter season. Adult coho salmon upstream migration coincides with brief peak winter discharges, typically peaking in January (Weitkamp et.al. 1995). Freshwater residence time is short (typically less than 2 weeks), though the NPS program has documented some individuals spending up to 20 days in the freshwater under ideal conditions.

Table 7.8 Monthly environmental and physical factors monitored in Redwood Creek for spawner years 1998-99 through 2004-05.

Spawner Year	Total Rainfall (in)				Mean Daily Discharge (cfs)				Max Daily Discharge (cfs)			
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
1998-1999	3.28	1.49	5.27	8.47	7.6	11.6	33.2	121.1	70.3	91.1	188.8	502.2
1999-2000	2.72	0.59	5.95	0.00	0.9	1.4	20.5	87.6	3.4	3.0	266.4	500.5
2000-2001	0.00	0.84	4.39	6.07	0.9	2.2	4.2	30.3	2.5	12.5	19.8	143.6
2001-2002	0.00	0.00	0.83	3.56	N/A	N/A	N/A	49.5	N/A	N/A	N/A	338.1
2002-2003	2.18	13.04	1.23	1.83	10.8	128.1	29.0	11.6	316.2	1111.3	113.1	80.1
2003-2004	2.62	3.45	7.21	6.38	1.0	5.2	N/A	32.4	2.4	11.4	N/A	64.8
2004-2005	0.8	7.59	3.66	3.09	0.22	24.2	27.5	21.8	1.7	221.3	78.8	52.1

Table 7.9 Coho salmon run timing, average daily discharge by month, and Redwood Creek Peak Live plus Cumulative Dead (PLD), total carcasses and redds documented in the surveys for spawner years 1998-99 through 2004-05 within the Redwood Creek mainstem.

Spawner Year (SY)	Run Timing				Average Daily Discharge (cfs)				Redwood Creek PLD			
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds
1998-1999					7.6	11.6	33.2	121.1	9.4	39[a]	10	58
1999-2000[b]					0.9	1.4	20.5	87.6	8.4	10	1	7*
2000-2001					0.9	2.2	4.2	30.3	9.4	49	13	35
2001-2002					N/A	N/A	N/A	49.5	9.4	105[d]	63	47
2002-2003[b]					10.8	128.1	29.0	11.6	9.4	24[c]	3	7*
2003-2004					1.0	5.2	N/A	32.4	9.4	67	25	43
2004-2005					0.22	24.2	27.5	21.8	9.4	171[d]	76	93

a/ Includes two peaks, 7 weeks apart.
b/ Surveys missed peak numbers.
c/ Includes two peaks, 4 weeks apart
d/ Includes two peaks, 3 weeks apart
* Poor survey conditions resulted in low observer efficiency

7.2.2 Watershed Escapement History and Estimates

Escapement estimates for adults in Redwood Creek have been made using both the Peak Live plus cumulative Dead (PLD) and Area Under the Curve (AUC) method. In years where persistent high flows resulted in a low number of surveys, both methods likely under-represented the true escapement number. The AUC method is dependent on two variables, observer efficiency (OE) and fish residence time (RT) in

the freshwater following entry. In years where flows were high, both OE and RT were assumed to be lower than normal.

PLD Index Results

The PLD dataset for adult escapement within Redwood Creek includes 11 years of survey information (Figure 7.3). It should be noted that prior to SY 1997-98, redds and carcasses were not consistently counted. PLD estimates have ranged from 10 to 171 (Table 7.10). The results of SY 1999-00 and SY 2002-03 are not considered representative of actual mainstem escapement due to poor survey conditions. The 2004-05 spawner surveys had the highest PLD (171 adult coho) in the 11 year survey history. This is believed to be the strongest coho run since documentation of spawners were initiated in SY 1994-95. This is further supported by the total number of observed redds and carcasses (93 and 76 respectively).

Table 7.10 Coho salmon spawning survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for Redwood Creek.

Year	Number of Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total Redds	Source
1969	1	3.2	24	4	--	CDFG
1977-78	1	3.2	36	3	--	CDFG
1985-86	1	7.2	50	--	--	CDFG
1994-95	5	8.4 [a]	58	22	--	NPS Fong 1995
1995-96	5	8.4 [a]	27	18	--	NPS Fong 1996
1996-97	6	8.4 [a]	57	15	--	NPS Fong 1997
1997-98	7	9.4 [b]	65	30	80	NPS Manning 1999
1998-99	11	9.4 [b]	39 [c]	10	58	NPS CSRP
1999-00	6	8.4 [a]	10	1	7 *	NPS CSRP
2000-01	5	9.4 [a]	49	13	35	NPS CSRP
2001-02	5	9.4 [b]	105 [d]	63	47	NPS CSRP
2002-03	5	9.4 [b]	24 [e]	3	7 *	NPS
2003-04	6	9.4 [b]	67	25	43	NPS
2004-05	7	9.4 [b]	171 [f]	76	93	NPS

a – Includes the main stem of Redwood Creek and Fern Creek
b – Includes the main stem of Redwood Creek, Fern Creek, and Kent Creek
c – Includes two peaks, 7 weeks apart
d – Includes two peaks, 22 days apart
e – Includes two peaks, 33 days apart
f – Includes two peaks, 25 days apart
* - Poor survey conditions resulted in low observer efficiency

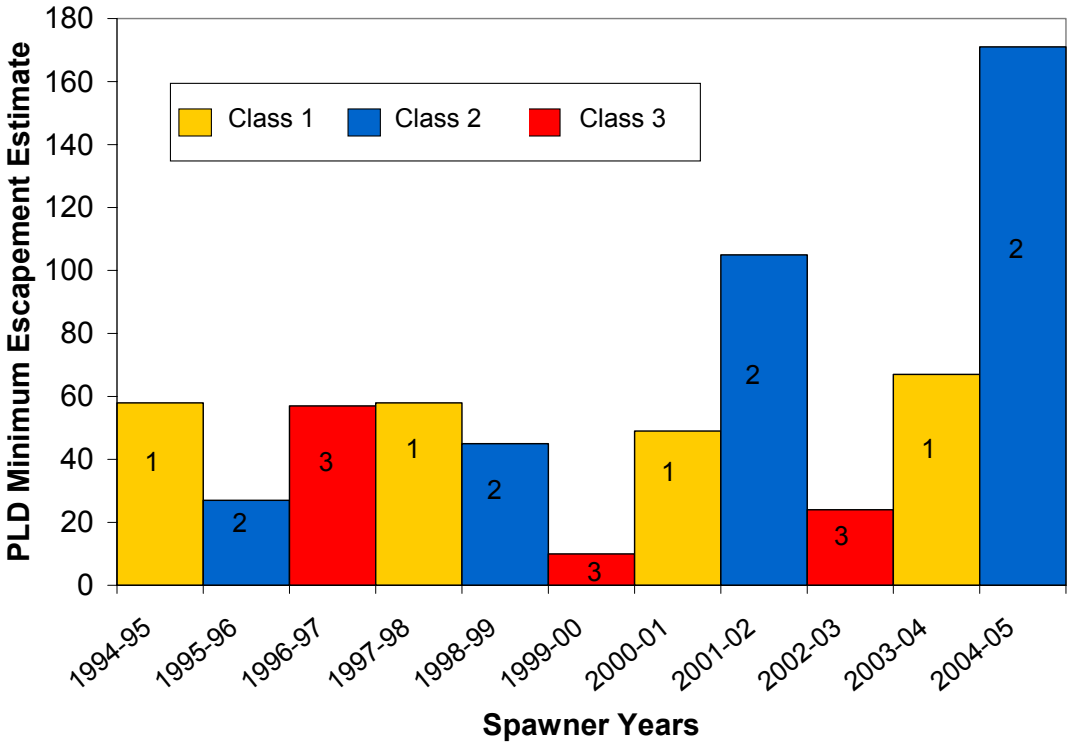

Figure 7.3 Redwood Creek Coho Salmon PLD Index Escapement results winter 1994-1995 through winter 2004-2005.

AUC Escapement Estimate

The PLD index is assumed to be a minimum count of fish within a watershed, as it is based on actual observations. The NPS has also used the AUC method to estimate adult escapement within Redwood Creek (Table 7.11). This method requires more consistent surveys and allows for an estimate of survey quality (observer efficiency) and the residence time of fish within the watershed. This method will tend to overestimate fish numbers where there are multiple peaks of fish or if there is a large interval between surveys. Only live fish are calculated using this technique.

Table 7.11 Coho salmon spawning survey Area Under the Curve (AUC) estimates for Redwood Creek, 1997-98 through 2004-05.

Year	Number of Surveys	Date of Entry	Mean Survey interval (days)	Survey Length (km)	AUC Range 100% OE [1] RT 8-17 days	AUC Range 50% OE [2] RT 8-17 days	AUC Range for OE & RT reported in literature	Redwood Creek PLD
1997/98	7	23 Nov 97	7.5	9.4	89-188	177-376	145-195	65
1998/99	11	29 Nov 98	8.6	9.4	39-83	78-167	64-87	39 [a]
1999/00	6	1 Jan 00	11.8	8.4	8-17	16-35	13-18	10
2000/01	5	15 Dec 00	13.0	9.4	74-157	148-314	121-163	49
2001/02	5	7 Dec 01	11.3	9.4	116-247	233-494	190-257	105 [b]
2002/03	5	10 Dec 02	14.0	9.4	22-46	43-92	35-48	24 [c]
2003/04	6	11 Dec 03	6.3	9.4	43-91	86-182	70-94	67
2004/05	7	6 Dec 04	8.3	9.4	169-359	338-718	276-373	171 [d]

a- Includes two peaks, 7 weeks apart
b- Includes two peaks, 22 days apart
c- Includes two peaks, 33 days apart
d- Includes two peaks, 25 days apart

7.2.3 Live Fish, Carcass, and Redd Observations

Information on live fish, carcasses, and redds are collected during each field survey. Information on sex ratios for live fish and carcasses are reported in Table 7.12. While live fish lengths are estimated, carcasses are handled to definitively determine sex, spawn success, fork length (FL), and for collection of a genetic sample. The results of carcass measurements show that males are generally between 56-70 cm, with females averaging 50-67 cm and jacks averaging from 37-49 cm.

Table 7.12 Sex ratios (Males, Females, and Jacks) and size observation of live coho observed during peak spawning surveys and carcasses from Redwood Creek spawner surveys, winter 1997-98 thru 2004-05.

		Live Coho				Carcasses			
		#	%	Mean FL	FL SD	#		Mean FL	FL SD
97-98	M	12	26	57.9(n=12)	5.42	6	25	56.0(n=3)	6.56
	F	24	52	56.9(n=24)	4.85	7	29	54.8(n=6)	4.07
	J	4	9	40.0(n=4)	0.00	4	17	39.7(n=7)	1.25
	Unk	6	13	53.3(n=6)	4.08	7	29	60(n=2)	7.07
	All	46	100			24	100		
98-99	M	8	22	61.3(n=8)	3.54	2	14	62.0(n=2)	2.83
	F	16	44	53.8(n=16)	3.87	6	43	52.3(n=6)	2.58
	J	6	17	36.7(n=6)	5.16	5	36	42.2(n=5)	2.59
	Unk	6	17	55.0(n=6)	4.47	1	7		
	All	36	100			14	100		
99-00	M	3	33	56.7(n=3)	11.55	0	0		
	F	4	44	62.5(n=5)	11.9	1	100	55.0(n=1)	
	J	0	0			0	0		
	Unk	2	22	67.5(n=2)	3.54	0	0		
	All	9	100			1	100		
00-01	M	4	9	60.0(n=4)	7.07	3	23	62.5(n=2)	3.54
	F	14	30	55.0(n=14)	4.39	6	46	66.8(n=5)	2.94
	J	28	61	39.1(n=28)	4.31	3	23	42.7(n=3)	4.62
	Unk	0	0			1	8	55.0(n=1)	
	All	46	100			13	100		
01-02	M	52	56	59.2(n=51)	8.25	19	37	70.1(n=19)	6.31
	F	31	33	56.7(n=30)	6.34	20	38	65.4(n=20)	5.28
	J	1	1	45.0(n=1)		0	0		
	Unk	9	10	57.1(n=7)	6.99	13	25	64.9(n=7)	4.6
	All	93	100			52	100		
02-03	M	2	13	65.0(n=2)	7.07	0	0		
	F	10	67	53.6(n=7)	3.78	1	20	50.0(n=1)	
	J	2	13	42.5(n=2)	3.54	4	80	36.5(n=4)	8.19
	Unk	1	7	55.0(n=1)		0	0		
	All	15	100			5	100		
03-04	M	19	32	62.0(n=19)	6.96	10	36	63.8(n=8)	7.32
	F	26	43	59.6(n=25)	4.55	13	46	64.2(n=12)	5.39
	J	13	22	35.4(n=13)	6.91	2	7	40.5(n=2)	0.71
	Unk	1	2	55.0(n=1)		3	11	64.0(n=2)	1.41
	All	59	98			28	100		
04-05	M	69	40	65.1(n=68)	5.50	18	26	67.2(n=15)	4.68
	F	82	48	60.1(n=78)	5.13	40	58	63.3(n=40)	4.78
	J	9	5	38.3(n=9)	2.50	1	1	70.0(n=1)	
	Unk	11	6	60.6(n=8)	6.23	10	14	49.0(n=1)	
	All	171	100			69	100		

7.2.4 Redwood Creek Watershed Summary

The emerging picture from 11 winters of coho spawner surveys on Redwood Creek (Figure 7.3) reveals the presence of two strong year classes (year class 1 and 2) and one weak year class (year class 3). Previously, year class 3 was probably the as strong as year class 1, with a PLD index of 57 during the 1996-97 spawning run. However, the resulting cohort probably suffered high mortality during the last large-scale El Nino Southern Oscillation (ENSO) event in 1997-98. This event caused high flows during the winter of 1997-98 which may have resulted in low overwinter survival for the juvenile coho. Results of adult escapement and summer juvenile density monitoring indicate that the overwintering year class during the

height of El Nino was the most heavily impacted and marks the shift of that cohort to the weakest year class. Although low spawner counts for the last two runs of this year class may be due in part to poor survey conditions during the winters of 1999-2000 and 2002-03, juvenile density observations support the notion that this became, and now remains the weakest year class. The year class 2 has steadily increased during the past four generations with a PLD increasing from 27 to 171 and AUC range increasing from 64-87 to 276-373 when using the observer efficiency and residence time most commonly reported in literature.

7.3 Pine Gulch Creek Escapement History and Creek Estimates

The dataset for the adult escapement within Pine Gulch Creek includes five years of survey information following the discovery of one adult coho salmon during the SY 2000-01. Since this discovery, adult coho have been sighted in the watershed during surveys three out of the last four years. Summer juvenile coho surveys and spring downstream migrant traps have confirmed that a self propagating coho run does occur in Pine Gulch Creek. Although observations are still scarce, SY 2001-02 year class does appear to be getting stronger while the SY 2000-01 spawner year class is the weakest of the three year classes.

Table 7.13 Coho Salmon Spawning Survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for the Pine Gulch Creek mainstem.

Year	Year Class	Number of Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
2000/01	1	3	7.0	1	0	0	NPS-PRNS
2001/02	2	2	9.0	2	0	2	NPS-PRNS
2002/03	3	2	8.0	2	2	1	NPS-PRNS
2003/04	1	6	9.0	0	0	0	NPS-PRNS
2004/05	2	3	10.0	3	0	3	NPS-PRNS

a/ Includes two peaks, 7 weeks apart.

Pine Gulch Creek Year Watershed Summary

Year Class 2

In winter 2001-02, NPS staff conducted two spawner surveys on Pine Gulch Creek. During these surveys a spawning pair as well as two coho redds were observed in the Dogtown area of the watershed. During the summer of 2002 a basinwide survey was conducted on the mainstem of Pine Gulch Creek. Within the 8.4 kilometer basinwide survey area, a total of 285 pools accounted for 45% of the total habitat units. Staff snorkeled 22.5% (64) of the pool units, of which 39 contained coho salmon juveniles. The raw count of 239 fish was calibrated to 271 based upon electrofishing survey results. The calibrated average of coho juveniles per pool was 4.23 resulting in basinwide snorkel estimate for cohort year class 2 is 1,205 ± 337 (95% confidence interval) (Ketcham and Brown 2003).

A total of 576 coho smolts were observed leaving the watershed in spring 2003. Comparison of this smolt census with the summer 2002 coho juvenile population estimate shows that overwinter survival was approximately 48% (stated error range shows 37% to 66% overwinter survival). This smolt total is likely far lower than the actual count leaving the watershed, as the trap was non-operable for a total of 12 days on two separate occasions April 12-15 and May 5-12 as a result of high flows bypassing the trap site. High numbers of smolts were observed during the period before and after the April bypass flow, and prior to the May bypass flow. Because smolts are known to group and leave during such higher flow events, it is assumed that far more than the 576 that passed through the trap and therefore the 48% overwinter survival are minimum estimates.

Based on the three coho redds and three adults observed during the 2004-05 spawner surveys, it is assumed that at least three to six coho survived to spawn from year class 2. Assuming six adult coho were required to construct the three observed redds, the smolt to adult survival rate would be 1.04%. Based on the summer basinwide estimate of 1,205 juvenile coho, the juvenile to adult survival rate for year class 2 is 0.50%.

Year Class 1

Year class 2 appears to be stronger than year class 1 one thus far in both escapement and survival rates. Although no returning adult or definite redds were observed during the 2003/04 spawner year, a basinwide survey conducted during the summer of 2004 revealed the presence of juvenile coho in the watershed (Ketcham et al. 2005b). However, based on the low numbers of juvenile coho observed (estimate is 110 coho fry) during the 2004 basinwide surveys it is likely that only one pair of adult coho successfully spawned during the 2003/04 spawning season. During the summer of 2001 a basinwide estimate of 589 juvenile coho were calculated for the mainstem of Pine Gulch and 249 coho smolts were counted leaving the watershed in 2002 (Ketcham and Brown 2003). Assuming two coho adults returned to Pine Gulch Creek from year class 1 the smolt to adult survival rate would be 0.80% and the juvenile to adult survival rate would be 0.34%.

7.4 Cheda Creek Escapement History and Creek Estimates

The dataset for adult escapement within Cheda Creek includes seven years of survey information and has documented the return of coho to a small tributary stream to Lagunitas Creek. Because of its small size and presence in the Lagunitas system, it is likely that spawner patterns in Cheda Creek are directly connected to those observed in the mainstem Lagunitas Creek (See section 7.5). Our observations of Cheda are intended to determine how a small downstream tributary is used by spawners in the context of the entire watershed.

The PLD index ranges from zero adults for the first three survey years to 17 adults observed in SY 2004-05. The first observed returning year class (SY 2001-02) appears to be coming back strong with both live adult observations and redd observations. The presence of one redd and live female observed above the fish passage structure constructed in 2000 is a promising sign of recovery and documentation of the projects success.

Table 7.14 Coho Salmon Spawning Survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for Cheda Creek.

Year	Number of Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
1998/99	2	N/A	0	0	0	NPS-PRNS
1999/00	1	N/A	0	0	0	NPS-PRNS
2000/01	2	1.4	0	0	0	NPS-PRNS
2001/02	6	1.2	4	0	3	NPS-PRNS
2002/03	3	1.2	2	1	1	NPS-PRNS
2003/04	3	1.2	1	0	6	NPS-PRNS
2004/05	4	1.3	17[a]	1	6	NPS-PRNS

a/ Includes two peaks, 3 weeks apart.
N/A-Survey Area Not Defined

7.5 Lagunitas Creek Watershed Summary for comparison (from MMWD 2005)

The PLD index data have not been consistently gathered for all creeks in the project area and can vary in quality depending on the number of surveys conducted and other factors. Data on the number of new redds provides a good overview of recent spawning activity in PRNS watersheds (Table 7.15). These data indicate the high annual variability in coho spawning activity and the relative importance of Olema Creek to spawning in the Lagunitas Creek drainage.

Table 7.15. Total Coho Redds in Lagunitas Creek Watershed, 1995-2005 (MMWD & PRNS)

Year	Lagunitas Creek mainstem	San Geronimo Creek (mainstem+tribs)	Devil's Gulch (+ Cheda)	Olema Creek (mainstem+tribs)	Total new redds	Olema Creek redd proportion
1995/96	70	6	10	NA	86	NA
1996/97	98	115	42	NA	255	NA
1997/98	80	107 + 14	46	126 + 7	380	35%
1998/99	92	46 + 14	31	42 + 1	226	19%
1999/00	139	58 + 3	3	10 + 7	220	8%
2000/01	119	56 + 18	11	86 + 48	338	40%
2001/02	79	102 + 43	59 + 3	58 + 31	375	24%
2002/03	71	39 + 22	24 + 2	5 + 12	175	10%
2003/04	124	139 + 66	48 + 6	88 + 21	492	22%
2004/05	120	140 + 18	112 + 6	92 + 45	633	22%

NA = not available.

The contribution of the Lagunitas Creek mainstem to overall spawning activity in that drainage is indicated by data collected by MMWD since 1982 (Table 7.16). Coho spawner counts and redd data show that much spawning activity takes place on Lagunitas Creek tributaries. Spawning on the mainstem takes place largely in Samuel P. Taylor State Park, upstream of PRNS-administered grazing lands.

Table 7.16. Coho Salmon Spawning Survey Data for Lagunitas Creek Mainstem

Year	Number of Surveys	PLD Index	Total Carcasses	Total New Redds	Source
1982/83	6	NA	NA	65	Bratovich & Kelly 1988
1983/84	6	NA	NA	26	Bratovich & Kelly 1988
1991/92	1	NA	NA	34	Wise 1992
1995/96	10	129[a]	NA	70	Trihey & Assoc. 1996
1996/97	8	170[a]	23	98	Trihey & Assoc. 1997
1997/98	10	46	27	80	MMWD
1998/99	8	56[b]	6	92	MMWD
1999/00	14	371[b]	37	139	MMWD
2000/01	14	181[b]	18	119	MMWD
2001/02	15	214[b]	25	79	MMWD
2002/03	13	283[b]	18	71	MMWD
2003/04	17	270[b]	23	124	MMWD
2004/05	17	448[b]	37	120	MMWD

a/ Peak live fish counts only, no cumulative dead.
b/ Corrected live fish observations reported by MMWD, may include repeat sightings of same fish
n.a. = not available.
MMWD = Marin Municipal Water District data

The mouth of Lagunitas Creek and adjacent floodplain supports activities associated with the Waldo Giacomini dairy. This 563-acre property, once tidal wetlands, was diked and drained in the early 1940s to create pastures. For many years, a gravel dam was constructed annually just below the confluence of Lagunitas and Olema creeks for irrigation and stock watering. The dam created an abrupt transition from fresh to saline water for smolts and spawning adults, eliminating the transition zone found in an unimpaired estuarine system. The transition zone allows smolting fish time to adjust to saline conditions and provides productive feeding zones where both freshwater and saltwater invertebrates are available.

Devil's Gulch has the longest period of spawner survey records for the Lagunitas Creek watershed (Table 7.17). CDFG biologist Eric Gerstung and warden Al Giddings noted live coho and steelhead observations from 1948 to 1977. Consultants for MMWD conducted surveys from 1982-84 and 1995-97. PRNS

expanded the sampling area further upstream in 1996-97. Prior to 1982-83, no more than two surveys were conducted in a single season and carcasses and redd data were not consistently collected. During a single survey in 1948, 174 coho and steelhead were counted in a 2.6 km reach. Between 1957-58 and 1976-77, peak counts of live coho ranged between 70 and 130 fish. Coho numbers had dropped by the 1990s, with PLD index values between 1995-96 and 2002-03 ranging from 10 to 78 fish. Surveys in 2004-05 exceeded counts even back to 1948. The total PLD index of 207 spawning coho is calculated from two observed peaks 25 days apart. In addition, the 112 redds counted in the watershed far exceeds any counts in the last decade.

Table 7.17. Coho Salmon Spawning Survey Data for Devil's Gulch

Year	Number of Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
1948	1	2.6	174[a]	NA	NA	Gerstung & Giddings
1957/58	2	2.4	100[b]	NA	74	Gerstung & Giddings
1960/61	1	2.6	77[b]	NA	NA	Gerstung & Giddings
1961/62	1	2.6	70[b]	NA	NA	Gerstung & Giddings
1964/65	1	1.6	91	76	NA	Gerstung & Giddings
1965/66	2	2.6	130[b]	NA	NA	Gerstung & Giddings
1976/77	1	2.4	100	90	NA	Gerstung & Giddings
1982/83	6	2.4	NA	NA	23	Bratovich & Kelly 1988
1983/84	6	2.4	NA	NA	11	Bratovich & Kelly 1988
1995/96	6	2.4	19[b]	NA	10	Trihey & Assoc. 1996
1996/97	3	3.2	47	20	42	Trihey & Assoc. 1997; PRNS
1997/98	8	3.2	27	9	46	PRNS
1998/99	6	3.2	26	6	31	PRNS
1999/00	2	3.2	10	1	3	PRNS
2000/01	4	3.2	14	2	11	MMWD
2001/02	11	3.2	46	12	59	MMWD
2002/03	5	3.6	87[c]	1	24	MMWD
2003/04	10	3.6	76[d]	12	48	MMWD
2004/05	14	3.6	207[e]	32	112	MMWD

a/ Peak live fish count includes both coho and steelhead, does not include carcass data.
b/ Peak live fish counts without accumulated carcass data.
c/ two peaks, 27 days apart
d/ two peaks, 24 days apart
e/ two peaks, 25 days apart
NA = not available.
MMWD = Marin Municipal Water District data; PRNS = Point Reyes National Seashore data

8.0 DISCUSSION AND CONCLUSION

Coastal Marin County watersheds are some of the most intensely monitored watersheds for coho salmon within the Central California Coast ESU. In addition to our NPS/DFG funded monitoring efforts on Olema Creek, Redwood Creek, Pine Gulch Creek and Cheda Creek, extensive monitoring is conducted by Marin Municipal Water District (MMWD) on Lagunitas Creek, Devils Gulch, and mainstem of San Geronimo Creek, and Salmon Protection and Watershed Network (SPAWN) on tributaries of San Geronimo Creek. Through these combined monitoring efforts, we have documented significant information about coho salmon behavior, distribution, and use of these small coastal watersheds.

The intensity of our life-cycle monitoring programs allow for larger scale characterization of patterns observed in the area. Though a relatively small geographic area, the coastal Marin watersheds support a significant proportion of the CCCESU coho salmon, as well as two genetically distinct subpopulations. Genetic evaluations suggest that coho salmon occurring in Olema Creek and Cheda Creek constitute part of the Lagunitas/Olema genetic subgroup that would likely encompass the entire Tomales Bay watershed. Genetic evaluations also suggests that the Pine Gulch Creek population represents an expansion of the Redwood Creek coho population to a new watershed (Garza and Gilbert 2003).

Winter 2004-2005 represented record spawner numbers for all watersheds in coastal Marin County. Adult escapement estimates and redd totals nearly doubled from last generation of this year class in SY 2001-02. The PLD estimate and redd counts in Olema Creek (182 coho and 92 redds), John West Fork (86 coho and 45 redds), and Redwood Creek (171 coho and 93 redds) represented the highest counts recorded in the past decade of monitoring. MMWD reported an estimated 1800 coho spawners and 496 redds in the Lagunitas Creek watershed (excluding Olema Creek), up from 286 redds and 735 live coho in SY 2001-02 (MMWD 2005).

The patterns represented in our monitoring data suggest regional influences on the coho salmon escapement observed over the past decade. Overall coho escapement within Marin County watersheds has been trending upward since the 1997-98 ENSO event likely triggered the Pacific Decadal Oscillation (PDO), shifting the dominant productivity from the Alaska Current to the California Current in the late 1990s. Since 1999, all three coho year classes in Olema Creek and Redwood Creek have shown a strong response to these changed ocean productivity patterns. This upward trend is most prominent in the documented return of coho salmon to the Pine Gulch Creek watershed in winter 2000-2001. Increases in adult escapement have translated into large shifts in juvenile coho density and smolt production at all monitoring locations. Continued monitoring efforts will allow for better characterization of year classes and annual productivity of coho salmon within coastal Marin County watersheds.

Most coastal Marin watersheds show the pattern of two stronger year classes SY 2003-04 (Year Class 1) and SY 2004-05 (Year Class 2), and one weak year class, SY 2005-06 (Year Class 3). The strongest year class prior to the 1997-98 ENSO event, we surmise that Year Class 3, was severely impacted as fish attempted to overwinter during the El Nino winter. As a result, anticipated coho escapement for SY 2005-06 is less than that observed the past two years.

As a measure of the overall watershed escapement, redd information is reported as density per kilometer (Table 8.1). This measure will be used for comparative purposes with the juvenile and smolt densities observed within the monitored areas in each watershed. Redd density per kilometer is also the only parameter reliably measured in all of the watersheds and will thus be used for watershed comparisons. Redd densities appear to be highly variable from year to year in the all of the unregulated streams surveyed in Marin County while Lagunitas Creek, a regulated stream, appears to remain fairly constant. This further supports the relationship of winter flows to spawning success in the coastal streams of Marin County.

Our data indicates a strong correlation between adult spawner density and the summer juvenile density, suggesting that year class is the dominant factor associated with population observations in these watersheds. We have observed that high winter spawner numbers have been consistent with increased juvenile densities the following summer, with peaks following SY 2000-2001 and SY 2001-2002.

8.1 Adult Escapement Monitoring Recommendations

Our program now includes 11 years of spawner surveys within the Marin County watersheds. Adult escapement is an important measure, and is conducive to involving many volunteers for spawner counts. We plan to continue these efforts, making a point to increase frequency (see methods below) so that we can employ additional statistical evaluation to determine actual escapement.

8.1.1 Methods

Adult spawner surveys have been conducted based on environmental conditions. Staff should work to increase survey frequency to improve our ability to conduct Area Under the Curve (AUC) estimates. The current surveys are adequate, and provide good AUC estimates in some years. This really will involve conducting a few more surveys under suboptimal conditions to estimate watershed escapement.

Coordination of volunteers is essential to the conducting watershed based surveys, but we have not been able to determine the efficiency of these volunteers in the identification of fish and redds. While fish are constantly moving and recounts would not readily improve results, redd identification and measurement is being investigated as a better measure of coho productivity within a watershed. Investigations by the CDFG in northern California indicate that measuring the surface area of redds can be a good measure of female effort and reproduction within a watershed (Gallagher and Gallagher 2005). Staff should follow up watershed scale surveys with redd based surveys to collect more detailed redd dimension information, as well as to confirm redd identification and/or missed redds as part of the survey. A better count of redds, and an understanding of female redd effort could be used as a measure to determine total eggs distributed in any given year.

8.1.2 Analysis

Staff should document date of entry for coho salmon and maintain datasets previously established and extended through this analysis. The analysis of spawner survey data should be reported annually with the results of the other coastal Marin County watersheds. Further analysis and standard protocols on redd observations should be made on a regional level as this is the only comparable data set to surveys performed by other agencies in Marin County. Data should also be compared to monitoring being performed on other California coastal streams in order to determine an accurate level of ocean survivorship. As noted above, additional effort related to redd investigations will add a valuable component (egg and escapement estimates) to the data already collected through this program. Many programs report egg to smolt survival as a measure of watershed success. The work we do between these life stages would simply complement the effort and provide more reasonable breakdown of potential population bottlenecks.

Table 8.1 Coho Spawner Survey Redd Density History for mainstem Lagunitas Creek, San Geronimo Creek, Devil's Gulch, Olema Creek and Redwood Creek including total redds, survey length and redd density.

Years	Lagunitas Creek			San Geronimo Creek			Devil's Gulch			Olema Creek			Redwood Creek		
	Total Redds	Survey Length	Redd Density	Total Redds	Survey Length	Redd Denisty	Total Redds	Survey Length	Redd Density	Total Redds	Survey Length	Redd Density	Total Redds	Survey Length	Redd Density
1997-98	80	10.7	7.5	107	7.0	15.3	52	3.2	16.3	126	13.4	9.4	74	7.4	10.0
1998-99	92	10.7	8.6	46	7.0	6.6	32	3.2	10	42	11.6	3.6	55	7.4	7.4
1999-00	139	10.7	13.0	58	7.0	8.3	3	3.2	0.9	10	7.2	1.4	7	7.4	0.9
2000-01	119	12.8	9.3	56	7.0	8.0	11	3.2	3.4	86	11.6	7.4	35	7.4	4.7
2001-02	79	12.8	6.2	102	7.0	14.5	59	3.7	16.1	58	11.6	5.0	29	7.4	3.9
2002-03	71	12.8	5.5	39	7.0	5.6	24	3.7	6.6	5	11.6	0.4	5	7.4	0.7
2003-04	124	12.8	9.7	139	7.0	19.8	48	3.7	13.1	88	11.6	7.6	43	7.4	5.8
2004-05	120	12.8	9.4	138	7.0	19.7	112	3.7	30.6	92	11.6	7.9	74	7.4	10.0

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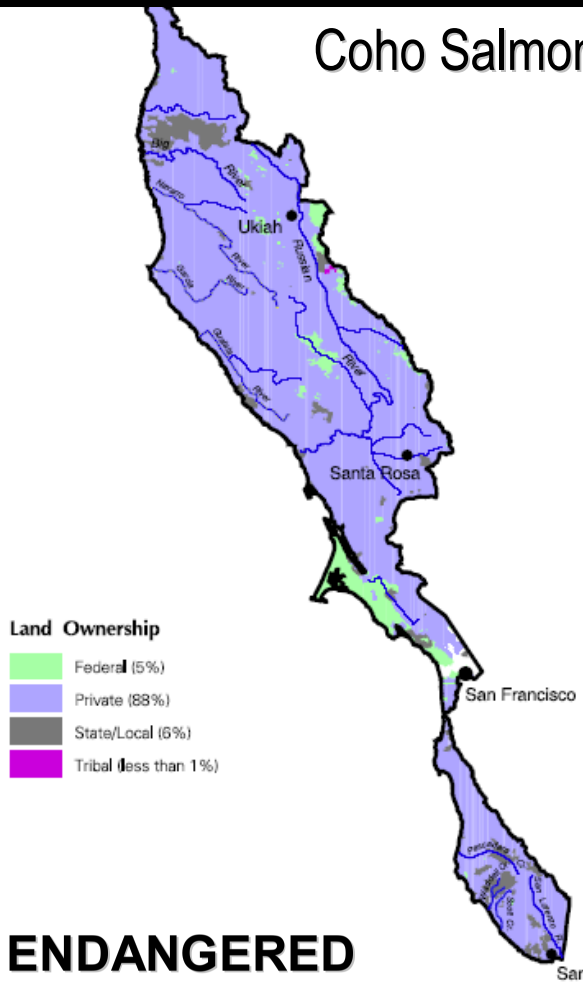
Appendix A

Local Salmon ESU Listings and Maps

National Park Service
Point Reyes National Seashore

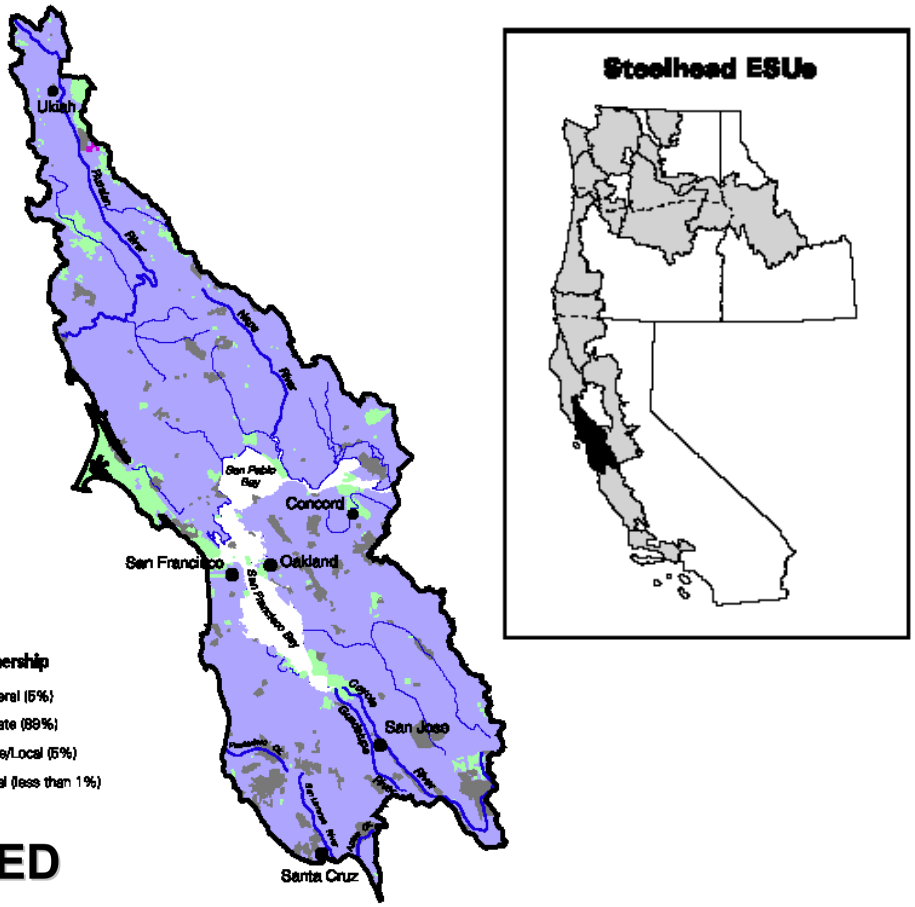
Coho Salmon CCCESU



Status: **ENDANGERED**

National Park Service
Point Reyes National Seashore

Steelhead CCCESU



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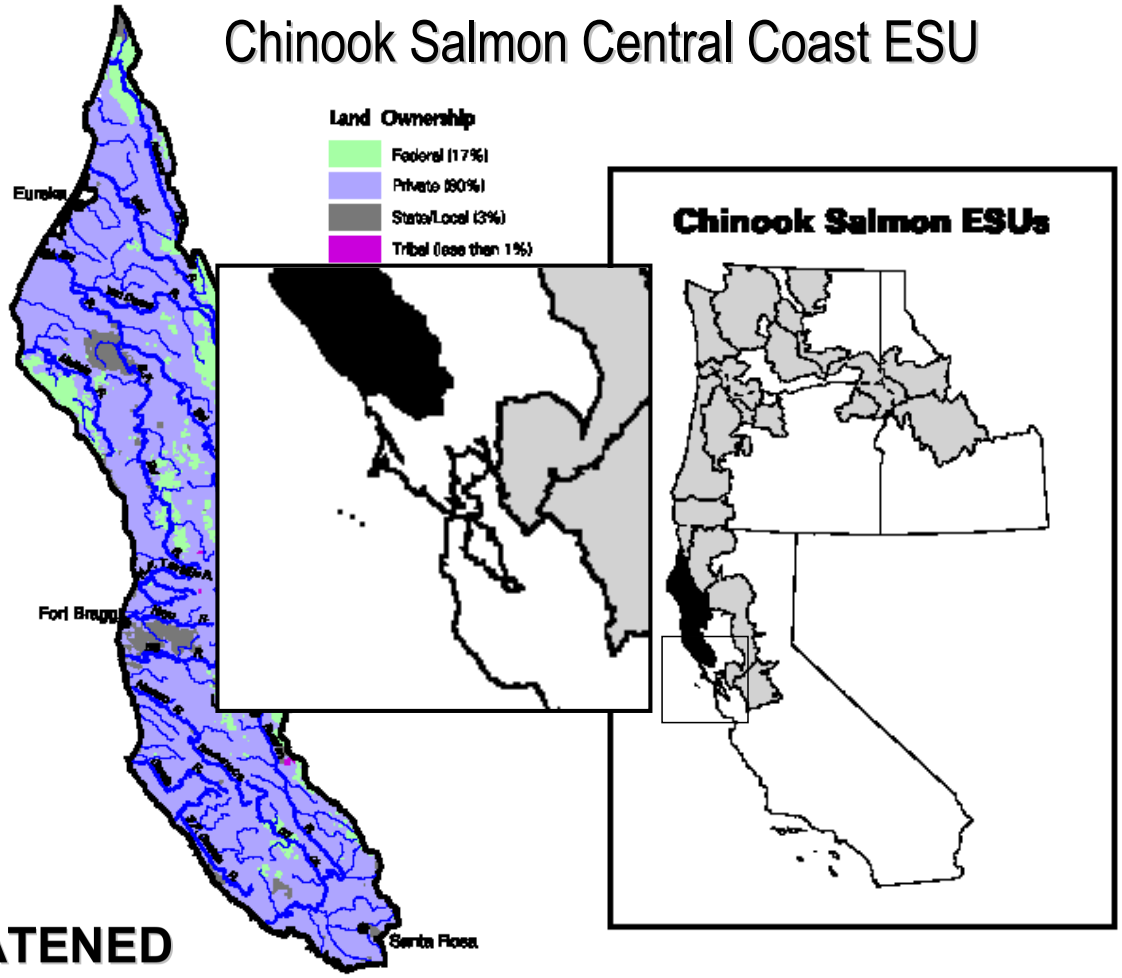
National Park Service
Point Reyes National Seashore

Chinook Salmon Central Coast ESU



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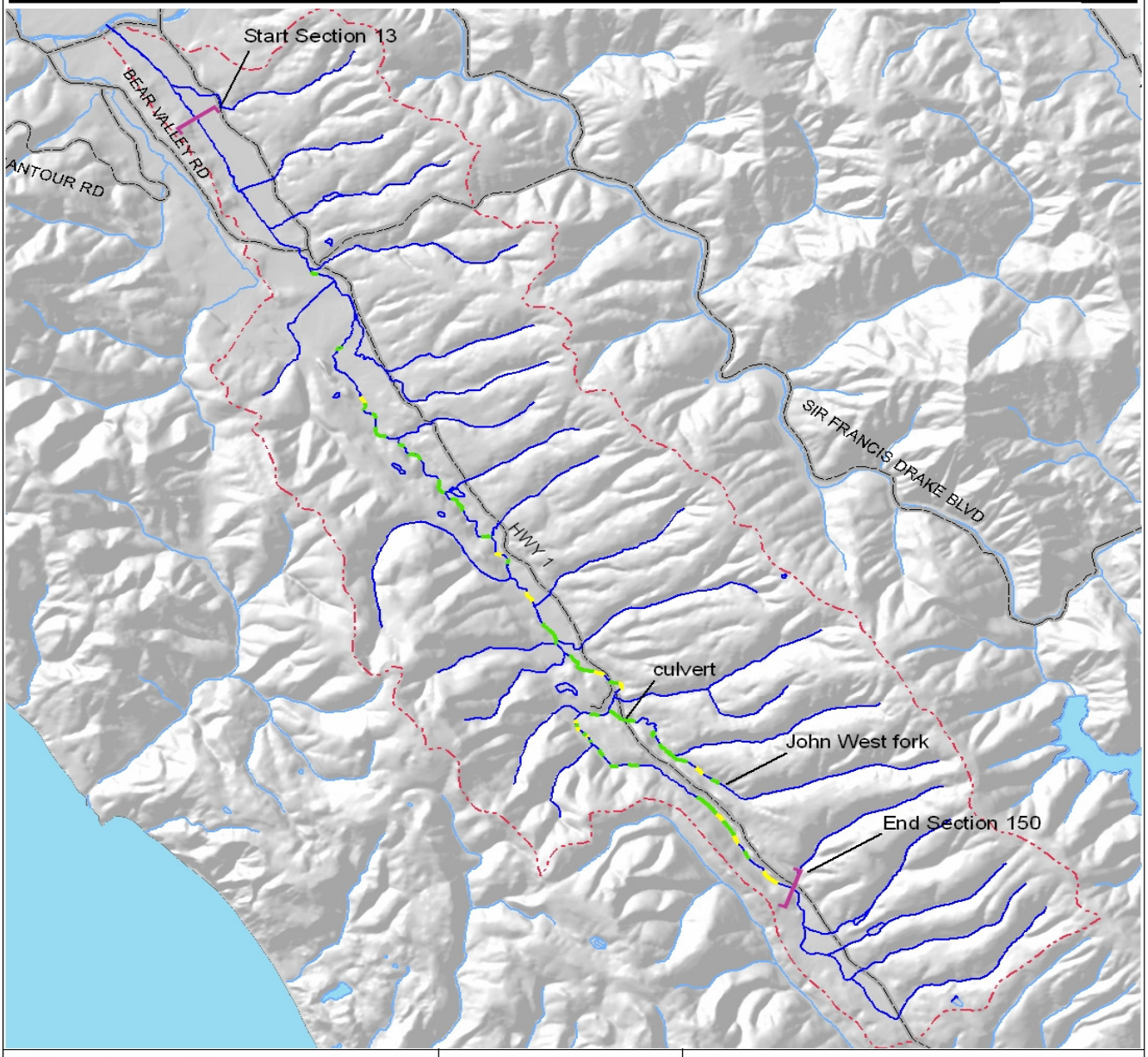
Appendix B

Olema Creek Watershed Redd Distribution Maps
1997-98 to 2003-04

note: 2004-05 is Figure 3.4

2003-2004 Coho Redd Density

Olema Creek and John West Fork



Coho redds per 100 meters

- 0
- 1 - 2
- 3 - 4
- 5 - 6
- 7 - 8
- Olema Creek watershed boundary

Map Location

National Park Service
Point Reyes National Seashore

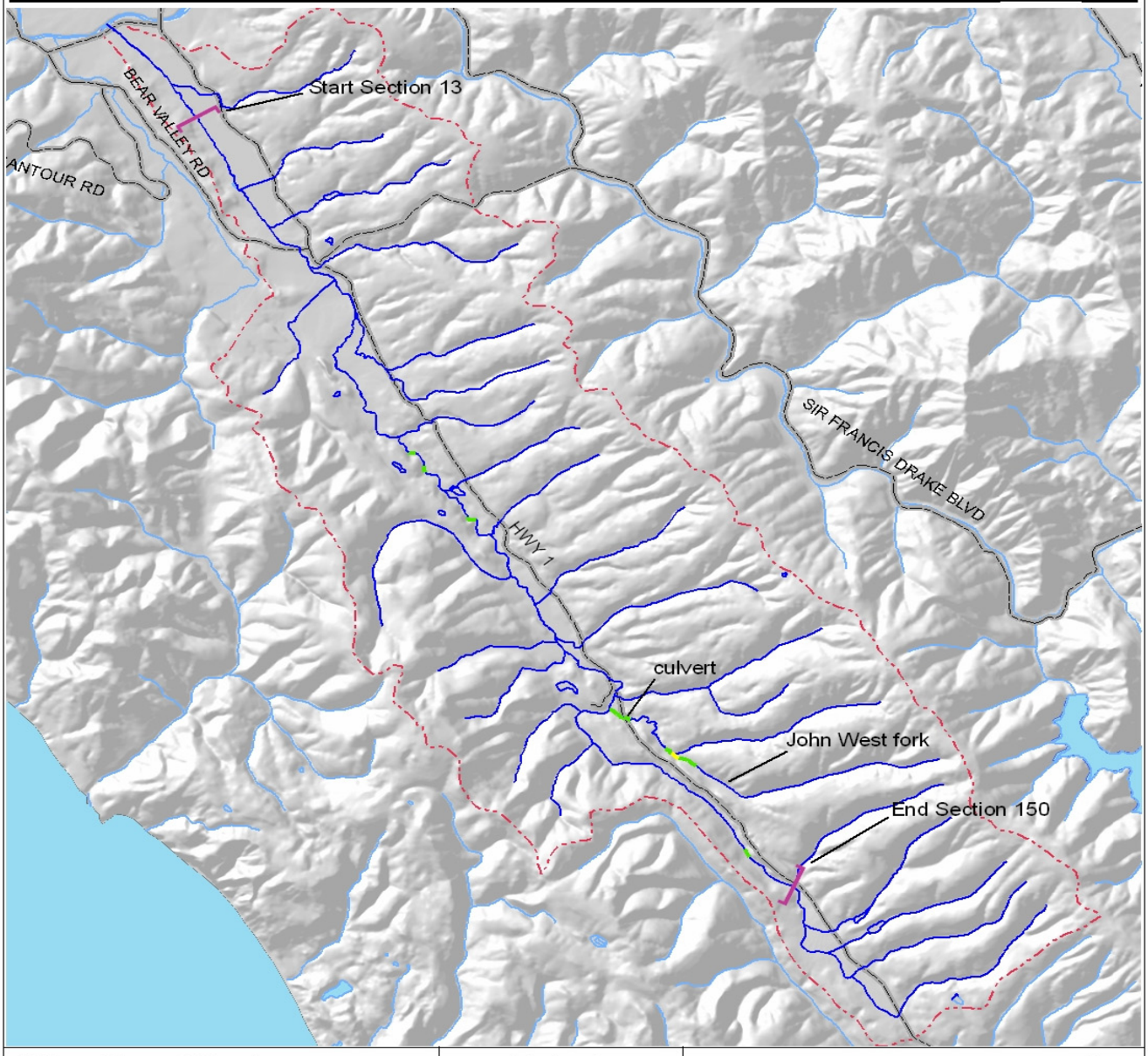
0 1 2 3 4

Kilometers

Plot date: Sept. 21, 2005 S:/GIS/projects1/Wildlife/Fish/2005_coho_redds

2002-2003 Coho Redd Density

Olema Creek and John West Fork



Coho redds per 100 meters

- 0
- 1 - 2
- 3 - 4
- 5 - 6
- 7 - 8
- Olema Creek watershed boundary

Map Location

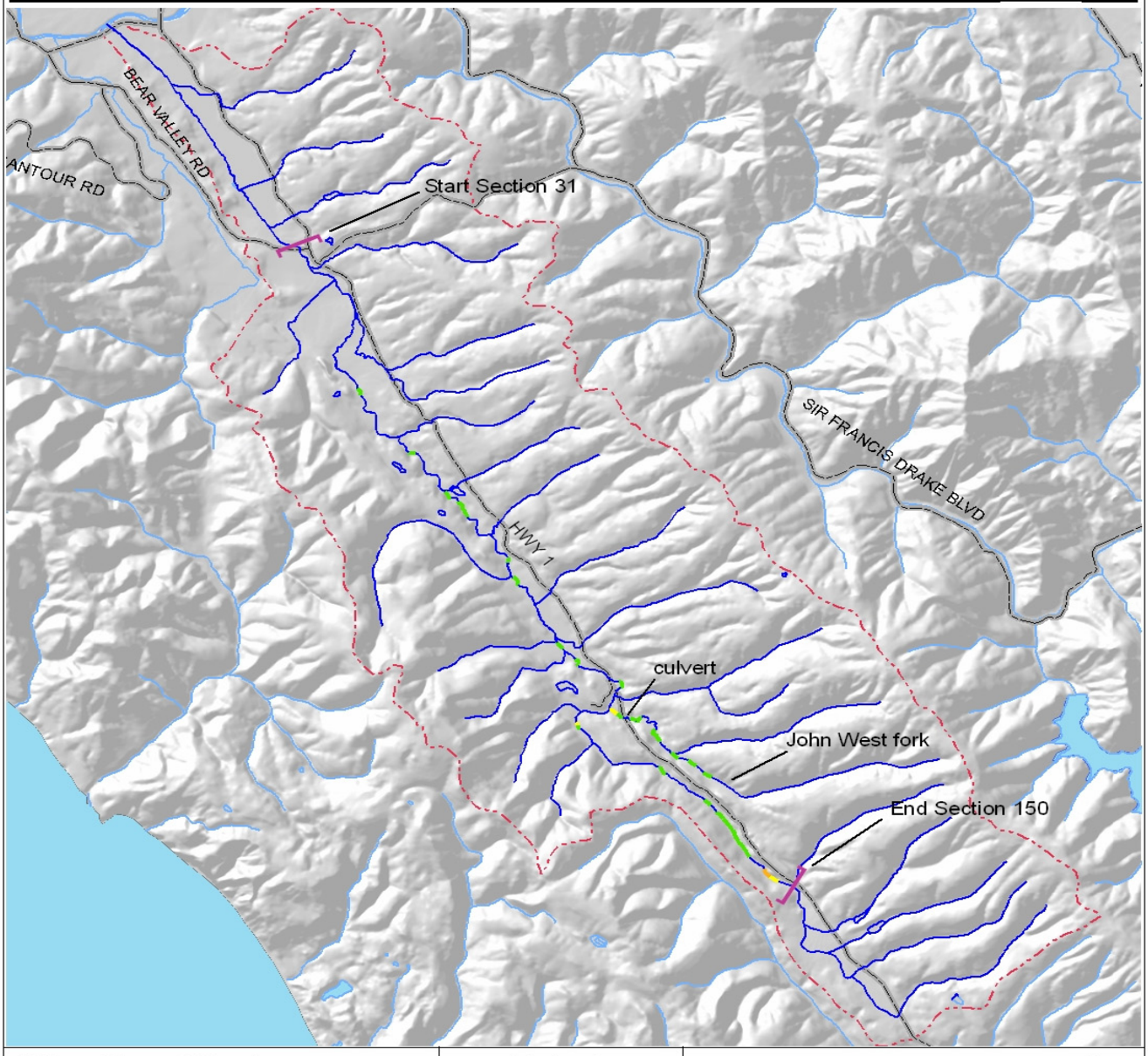
National Park Service
Point Reyes National Seashore

0 1 2 3 4
Kilometers

Plot date: Sept. 21, 2005 S:/GIS/projects1/Wildlife/Fish/2005_coho_redds

2001-2002 Coho Redd Density

Olema Creek and John West Fork



Coho redds per 100 meters

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- 3 - 4
- 5 - 6
- 7 - 8
- Olema Creek watershed boundary

Map Location

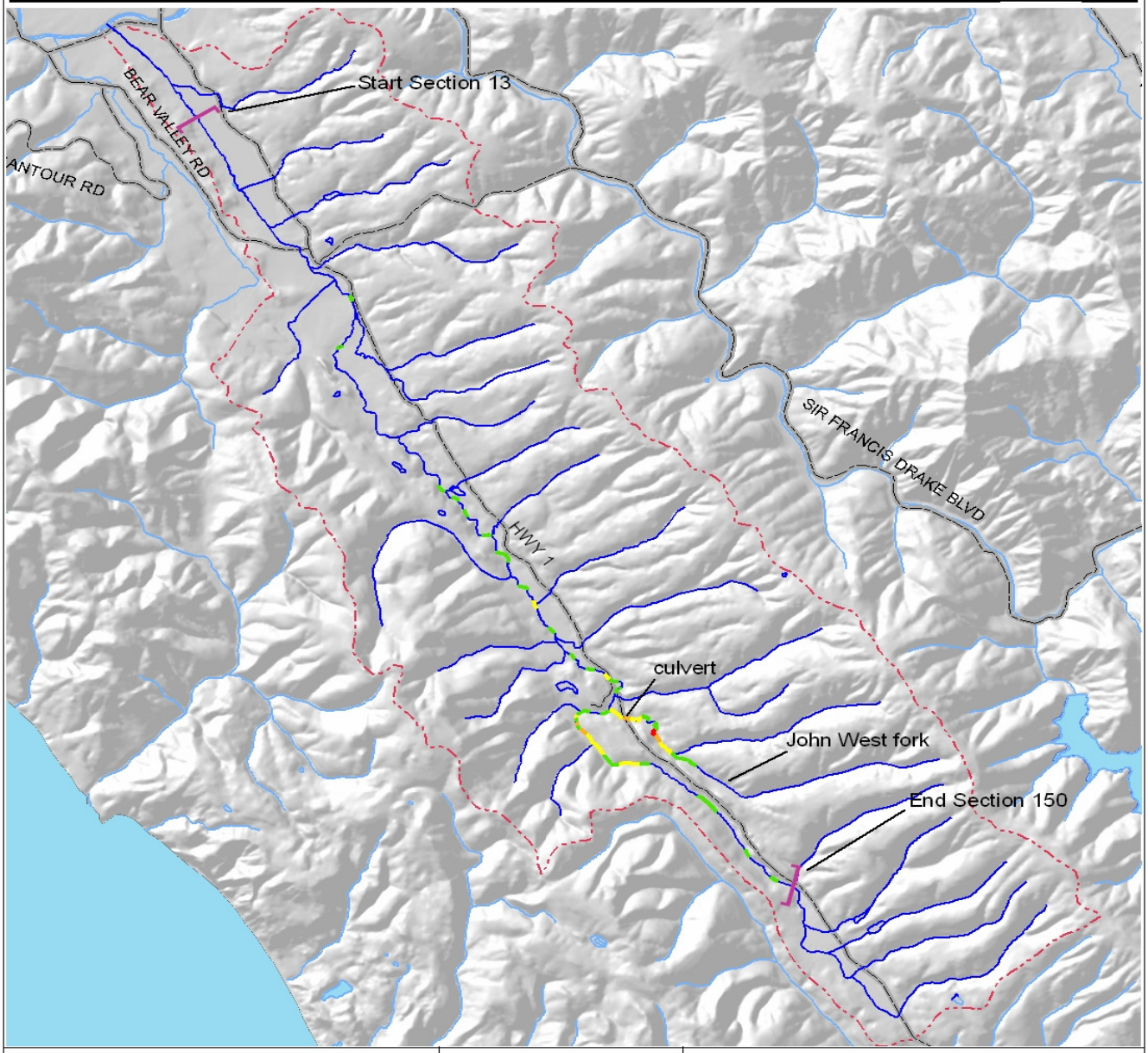
National Park Service
Point Reyes National Seashore

0 1 2 3 4
Kilometers

Plot date: Sept. 21, 2005 S:/GIS/projects1/Wildlife/Fish/2005_coho_redds

2000-2001 Coho Redd Density

Olema Creek and John West Fork



Coho redds per 100 meters

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- 3 - 4
- 5 - 6
- 7 - 8
- Olema Creek watershed boundary

Map Location

National Park Service
Point Reyes National Seashore

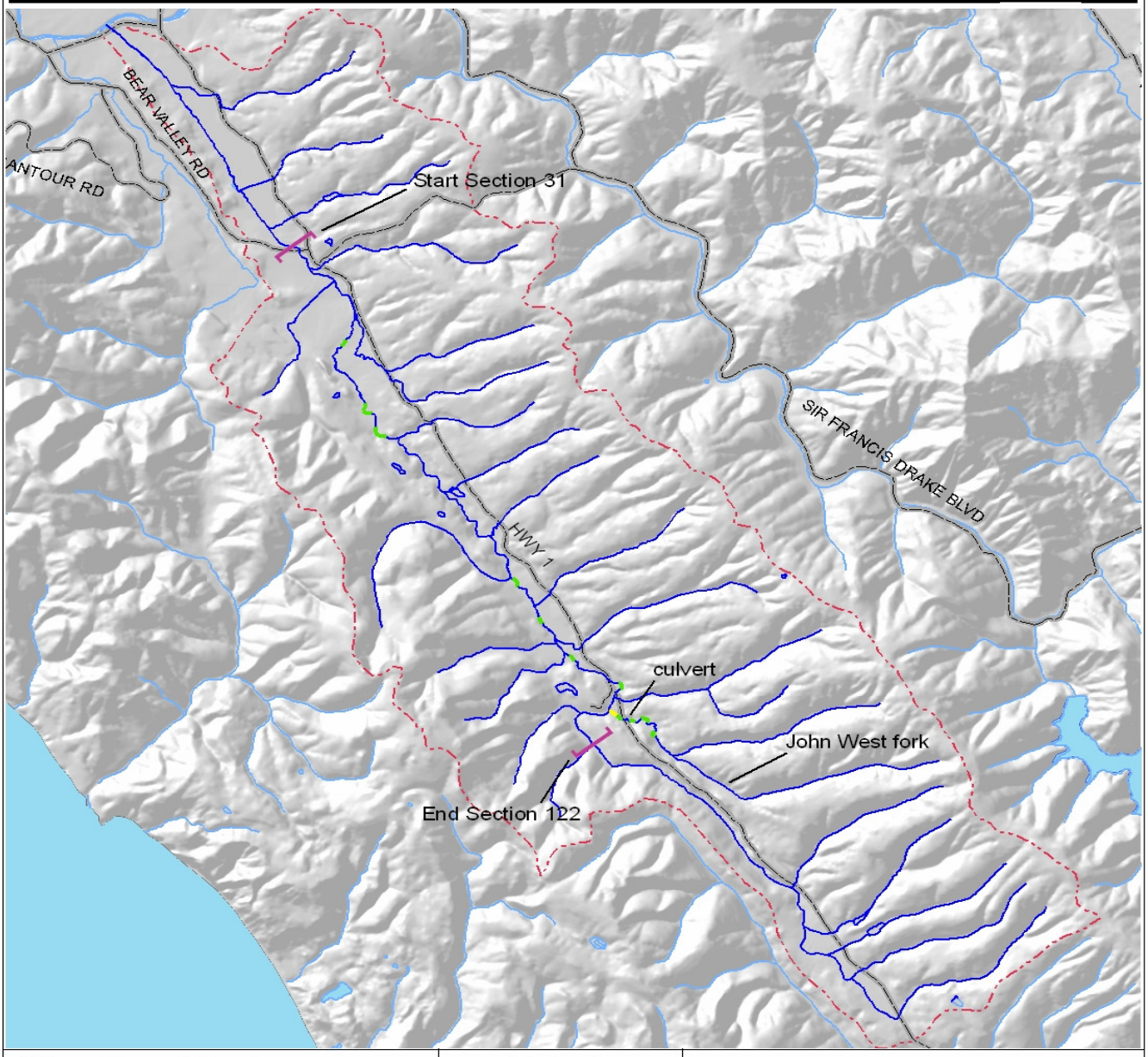
0 1 2 3 4

Kilometers

Plot date: Sept. 21, 2005 S:/GIS/projects1/Wildlife/Fish/2005_coho_redds

1999-2000 Coho Redd Density

Olema Creek and John West Fork



Coho redds per 100 meters

- 0
- 1 - 2
- 3 - 4
- 5 - 6
- 7 - 8
- Olema Creek watershed boundary

Map Location

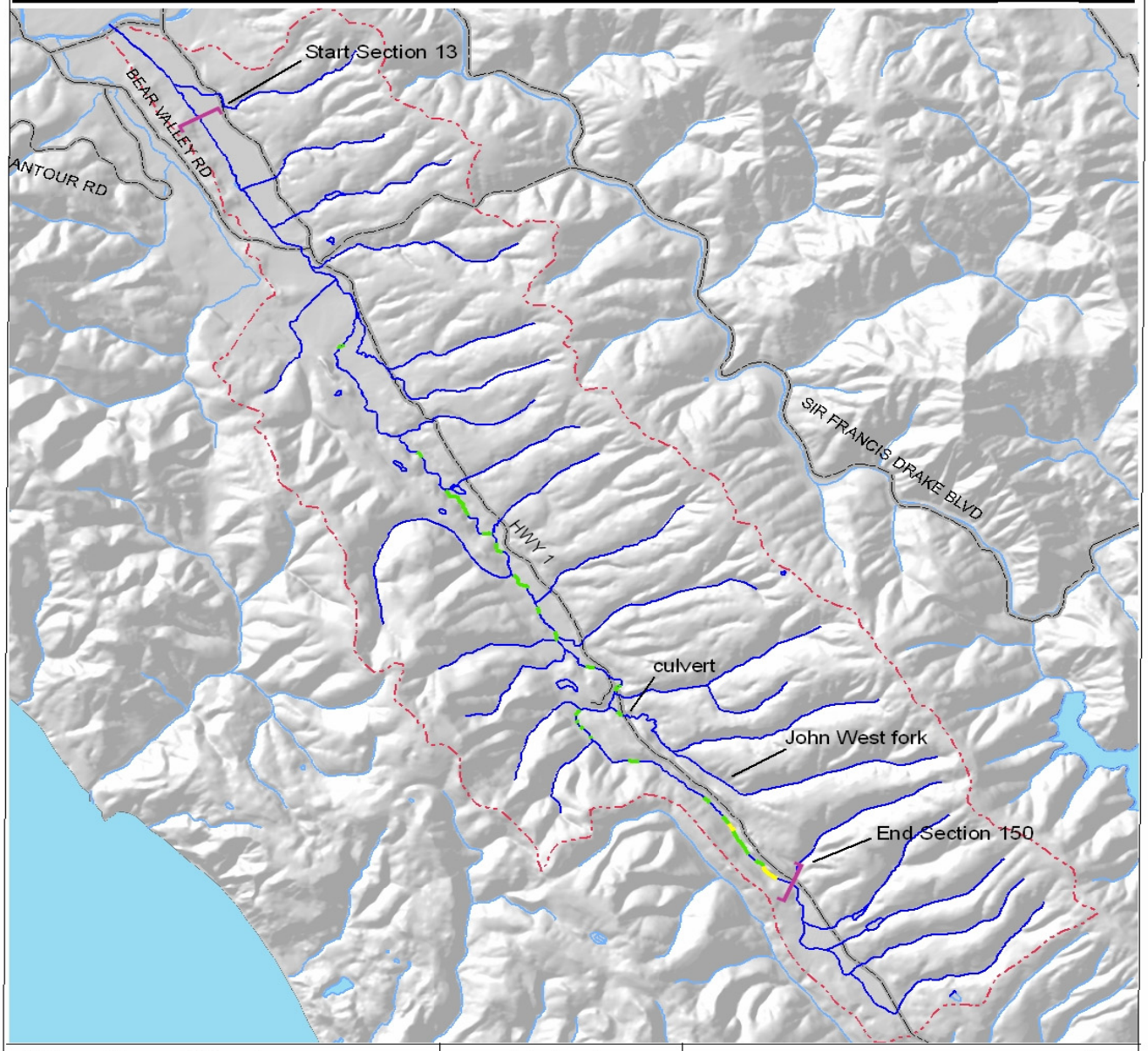
National Park Service
Point Reyes National Seashore

0 1 2 3 4
Kilometers

Plot date: Sept. 21, 2005 S:/GIS/projects1/Wildlife/Fish/2005_coho_redds

1998-1999 Coho Redd Density

Olema Creek and John West Fork



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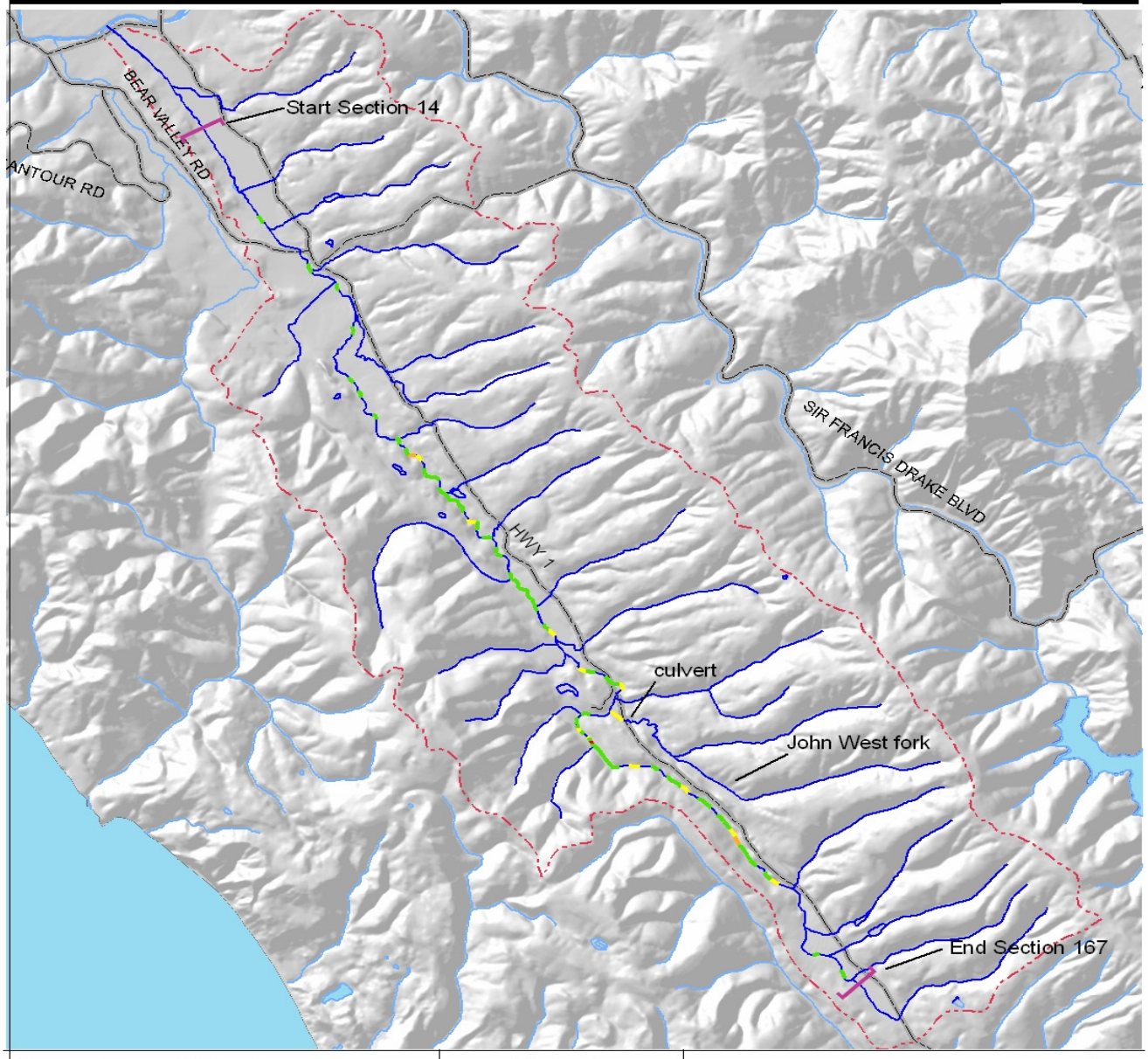
1997-1998 Coho Redd Density

Olema Creek and John West Fork



Coho redds per 100 meters

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- Olema Creek watershed boundary

Map Location

National Park Service
Point Reyes National Seashore

0 1 2 3 4
Kilometers

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